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by

John Stratton Hicky

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by

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Submitted in partial fulfillment of the
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ABSTRACT

The thesis identifies conditions associated with production cost overruns or underruns on major weapon systems. The analysis used U.S. military fighter/attack aircraft. First, relying on techniques developed in prior studies, measures of the technology embodied in aircraft and the cost of producing those aircraft were developed. Next, relationships between technology and cost were examined to create measures of "should costs", for each aircraft based on technology in the aircraft. These estimates of "should costs" were compared to actual costs to determine situations of cost overruns and underruns. Analyses of financial ratios of each aircraft´s prime contractor were used to determine if financial condition could explain the cost overruns or underruns experienced during production, by using several forms of regression analysis. This yielded models relating financial ratios to cost overruns or underruns. Major findings indicate that financial condition does partially explain production cost overruns and underruns, but the relationship is small.

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I. INTRODUCTION

This thesis is a follow-on to several studies involving methods for measuring state-of-the-art (SOA) of technology, extensions in technology and the cost of developing an SOA extension. This chapter will begin with a general overview of some of the more relevant literature and then describe how the concepts developed in that literature can be used as a foundation for the analysis conducted in this thesis.

A. PURPOSE

The primary objective of the thesis is to investigate measures of financial condition as explanations of cost overruns or underruns experienced during the procurement of high-technology weapon systems. Identifying conditions that are associated with cost over/underruns provides an initial step toward prediction of future cost of new, high-technology systems. This chapter will conclude with the general organization of the thesis and an outline of subsequent chapters.

B. LITERATURE REVIEW

Models designed to predict estimated cost of specific systems rely on measures of the amount of technology in those systems. The literature on technology measurement offers various broad approaches to determining the state-of-the-art (SOA) of technology for a given set of related systems, measuring extensions of technology and measuring the cost of advances in technology. The most relevant work in this area will be reviewed in the following paragraphs.

There is general recognition that the cost of SOA extension relates to the magnitude of the extension. Most of the research done to date has concentrated on measuring the amount of SOA extension represented by a particular new system. Each approach requires the knowledge of a number (n) of technology variables reflecting distinct properties or characteristics of the systems under study. Each approach also combines variables into a single SOA measure which reflects the "amount" of technology in a given system. The resulting measure then has a scale independent of the scales used for the individual technology characteristics (which are typically measured in differing types of units).

1. **Dodson and Graver, 1969.**

While SOA had been measured using numerous methods for many years, Dodson and Graver reported an important theoretical advance in 1969.[Ref. 1] Their innovation was to make use of convex (ellipsoidal) hypersurfaces to represent particular levels of SOA. In their approach three steps must be taken:

a. An operational definition of current SOA is specified. Dodson and Graver stipulated "recently implemented technology" as representing the current SOA.

b. "n" SOA-determining parameters are specified and measured for the kinds of systems or subsystems under examination. Since no single measures of SOA have yet been developed, the "n" SOA-determining parameters must be specified in such a way as to collectively describe the level of technology embodied in the kinds of systems or subsystems under examination.

c. An "n"-dimensional ellipsoid is then fit to the parameter measurements of an SOA-representative group of systems or subsystems. (Once the "n" SOA-determining parameters have been specified and measured across an appropriate sample, Dodson and Graver theorized that an SOA-describing ellipsoid could be fit to the data.) The technology in individual systems is then measured by the degree to which the systems are above or below the SOA surface.

2. **Dodson, 1970.**

Dodson later published an article reporting and expanding upon the results of his earlier work with Graver. In this article Dodson went on to suggest that the ellipsoid model would be appropriate only when all system attributes approach finite upper bounds:

> When the dimensions include one or more terms which do not approach a finite upper bound, the form is planar. Thus, the choice depends upon the nature of the SOA-determining parameters.[Ref. 2]

3. Alexander and Nelson, 1972.

A RAND report by Alexander and Nelson in 1972 began by stating an important limitation to the usefulness of quantitative models for measuring SOA. The limitation is that the progression of technology must conform to an assumption of "continuity":

> Continuity exists if two devices that appear at different times can be characterized by the same set of parameters. Continuity also requires that subsequent development can begin where prior development ended.[Ref. 3]

Like Dodson, Alexander and Nelson theorized the existence of a curvilinear relationship among technology parameters. But, also like Dodson, they used linear methods to analyze their empirical data.

4. Dodson, 1977.

The focus of this paper by Dodson was cost estimation for both R&D and procurement. Three indicators of technological capability were used and a multiple linear regression was run with the year of development as the dependent variable. The result was the following equation:

$$Y_e = B_1 + B_2 X_1 + B_3 X_2 + B_4 X_3$$

where

B_i were regression coefficients

X_i were three indicators of technological capability.

Y_e was the year of technology of a system. (i.e., the estimated year the system should have appeared, given the technology in the system.)

Y_e was calculated for each system in the sample.[Ref. 4] Dodson reasoned that if the year a system was actually produced was less than the year estimated by the regression equation, then that system was developed "before its time." Conversely, if the actual year of production was greater than the year estimated by the regression calculation for that system then the system was "behind the times." Differences between Y_e and the actual year a system was placed into service were used as measures of the SOA advance represented by a given system.

Dodson´s next step was to associate SOA advance with cost. Procurement cost was estimated from a cost estimating relationship (CER) which incorporated the year of technology as an independent variable. According to Dodson this is necessary to compensate for the fact that production technology changes through time. This implies a more advanced design would be more costly to produce with older manufacturing technology and more advanced production technology would cause the procurement cost to drop.

5. Gordon and Munson, 1981.

Gordon and Munson express SOA as a direct combination of values of the technology characteristics. This process can be termed the "judgmental weighing" approach. They suggest two general forms of SOA equations:

$$SOA = B_1 V_1 + B_2 V_2 + \ldots B_n V_n \quad (1)$$

and

$$SOA = V_1 \; [B_2 V_2 + B_3 V_3 + \ldots B_n V_n] \quad (2)$$

where

B_i = judgmentally assigned weights

V_i = the value of the ith technology describing variable.

The first version of the Gordon and Munson model is a simple linear combination of weighted characteristics, the second version is a multiplicative form intended for use when variable (V_1) must be present in the system.[Ref. 5]

Another contribution made by Gordon and Munson was to suggest the use of "factor analysis" as a method of grouping proposed technology parameters into clusters that have similar behavior or influence on SOA.[Ref 5: p. 8] Factor analysis accumulates the statistical influence of several correlated variables to form "factors." The method frequently enables the researcher to reduce the information content of a large number of variables into a relatively small number of factors (or composite variables). Factor "scores", the calculated values of the composite variables, can then be used for further analysis.

6. Knight, 1985.

Knight made two important contributions. He distinguished sharply between functional and structural measures of technology, while developing a relationship between the two. He also examined the movement of a functional measure of technology over time.[Ref 6: pp. 107-127] Knight defined the concept of functional measures of the systems he was studying as "The capability of each system to perform its intended tasks."[Ref. 6: p. 107]

7. **Greer, 1988.**

Greer's study created measures of the technology in systems and the extension in technology represented by new systems. Using these technology measures, he determined estimates of development time and development cost of systems. His work concluded with analyses that provide an opportunity to attribute differences between expected costs and actual costs, to specific causes.[Ref. 7]

Greer proceeded by using technology measures for each system in a "TIME" regression to predict the time that would be required for development. The predicted time was them input into a "COST" regression (with the residual set to zero to represent the system being developed in the time originally estimated) to calculate an **ex ante** cost estimate for each system.

His next step was to compare each system's actual development time to his calculated predicted time in order to produce a residual, **ex post**, time. He then used the cost regression equation to calculate a new cost estimate considering the residual time established for each system. The difference between the **ex ante** cost estimate and the actual time cost estimate was termed "Variance Due to Time." This represented the portion of cost variance that could be attributed to time variances alone.

Actual development costs were then compared with the cost estimates made using the cost regression and actual time inputs to determine a "Cost Control Variance." This variance indicated the quality of cost control for each system´s development.[Ref 7: pp. 81-88]

By measuring "cost variance due to time" and "cost control variances" Greer was able to establish apparent causes of total cost variances for each system analyzed. The comparisons indicated whether a cost variance was due to timing or cost control. Greer´s analyses of the comparisons also indicated that cost variances due to timing could be offset by opposing cost variances due to cost control measures.

He concluded that prediction of development time was a critical step in successfully estimating cost and in order to control costs the variances between predicted and actual costs must be explained. Analysis of the regressions developed, provided a basis for doing this.

C. EXTENSIONS OF TECHNOLOGY

One common approach for measuring extensions in technology relies on the idea of the "year-of-technology." [Ref. 3] In this approach time is related to technology measures in a multiple regression:

$$Y = a + b_1 X_1 + b_2 X_2 + \ldots + b_n X_n + e$$

where

Y = actual year the system becomes operational

b_i = regression coefficients

X_i = technology measures

e = residual

A predicted value from the regression equation for an individual system represents the "year-of-technology" for that system. If the actual year a given system was produced is less than its year-of-technology, it can be said that the system was produced "ahead of its time" and represents an advancement in technology.

As simplistic as this method seems, related work by Lienhard [Ref 8] tends to support the concept. Lienhard's paper studied the rate at which technology is improved, and how (whether) this rate changes through time. He studied several forms of technology (clocks, steam power, land transportation, air transportation) over extended time periods. As another researcher observed:[Ref 9]

> The most relevant observation to come from Lienhard's study was that the rate of improvement of a particular technology, once established, does not change. If this is literally correct (and his data do seem to support the observation), there could be some major implications for the cost, and even the feasibility of attempting to effect technological advances "before their time." If a desired advance could normally be expected to occur only by some quasi-naturally established date, attempts to accelerate this process would be very costly. Accordingly, the "year-of-technology" approach may be well reasoned.

The essence of the year-of-technology approach is to relate technology to time and use variations from the time line as indicators of the technology advancement represented by individual systems.

D. WHERE DO WE GO FROM HERE?

With the techniques from prior work available as a foundation, other questions can be examined. This thesis will use techniques for technology measurement and cost estimation to develop cost estimates for a sample of military aircraft. Measures of cost overruns or cost underruns will then be created by comparing actual cost with estimated cost. The central purpose of the thesis is to identify factors that explain these cost variances (over/under runs). The thesis will identify measures of financial condition of contractors who are responsible for producing the aircraft and analyze the relationship between contractor financial condition and cost variances. The purpose is to determine if contractors were predisposed to cost overruns or cost underruns.

1. Goals of the Thesis

The goals of this thesis are to utilize and expand upon the previously discussed literature as follows:

1. Utilize similar techniques to indicate whether aircraft produced for the Department of Defense (DOD) cost more or less than "expected."
2. Develop measures of production capabilities and efficiencies utilizing commonly available financial data.
3. Examine the relationships of financial indicators to production capabilities and efficiencies.
4. Hypothesize relationships between production capabilities and efficiencies with production cost.

5. Determine if financial data available prior to initiation of production could have indicated cost variances (overruns or underruns) for the sample of aerospace manufacturing firms. (Correlation and regression analyses will be used.)

6. Develop an initial model to assist in determining potential cost overruns or underruns prior to awarding a production contract, by utilizing the financial measures developed in the analyses described above.

E. ORGANIZATION AND OUTLINE OF REMAINING CHAPTERS

Chapters II and III are primarily a synopsis of work done by Dr. O. Douglas Moses to develop cost estimating models for aircraft produced for the Department of Defense (DOD).[Ref. 9]

1. Chapter II

Chapter II will provide a description of the source of the initial DOD aircraft data. It will discuss the process used for measuring extensions of technology in aircraft systems. It will also describe the process used for developing measures of production cost. Technology and cost measures are the two items needed to develop cost estimation models. Through Moses´ work, technology and cost measures have been created for four different components of aircraft:

1. Airframe
2. Aircraft Platform (airframe plus engines)
3. Avionics and weapons systems
4. Flyaway aircraft

2. **Chapter III**

Chapter III will discuss the association between production cost and the technology in aircraft systems. Cost estimation models will be developed and the process of establishing measures of cost over/underruns through regression analysis will also be discussed. The concept of cost variances between actual and expected production costs, given a measured level of technology embodied in each aircraft, will be discussed.

3. **Chapter IV**

Chapter IV will present the building blocks for the thesis´ hypotheses relating financial condition to cost over/underruns. Chapter IV is divided into four subsections as follows:

1. Presentation of the hypothesis that financial relationships or conditions are influencing factors on production, and therefore on the likelihood of cost overruns or underruns.

2. The process used to examine a firm´s financial condition by categorizing its financial status into five separate "aspects."

3. The process used to measure financial aspects by the use of financial data commonly available in the form of financial ratios.

4. Discussion leading to the conclusion that certain specific ratios may be key indicators of the five financial aspects.

4. **Chapter V**

Chapter V provides a description of the analyses of hypotheses concerning cost variances and their association to financial ratios. The hypotheses concerning relationships between financial data and production costs will be tested for measures of cost control based on the three specific measure of cost established in Chapter III.

5. Chapter VI

Chapter VI will provide calculation and analyses of ratio variables and initial univariate tests of the hypotheses relating financial ratios to cost over/under runs. It presents the regression rationale, procedures and findings. It includes the regression models of significance related to cost variance and a discussion of results for model variables tied back to hypotheses presented in Chapter IV.

6. Chapter VII

Chapter VII presents conclusions regarding the analyses and proposes a preliminary model for predicting cost over/underruns based on these conclusions.

II. TECHNOLOGY AND PRODUCTION COST MEASUREMENT

This chapter is organized into four sections. The first section describes the basic sample on which the analysis is conducted. The second section describes the process used to measure the "state-of-the-art" of technology for aircraft. The third section discusses the process used to measure the technology extension embodied in each aircraft in the sample. The fourth section discusses the process used to measure production "cost" for each aircraft in the sample. As previously mentioned, this chapter and the following chapter primarily represent a synopsis of work already performed by Moses. [Ref. 9]

A. SAMPLE

The population for this thesis was originally defined as U.S. military aircraft. The sample represents a subset of military aircraft for reasons set out below. The source of data was the U.S. Military Aircraft Cost Handbook [Ref. 10], produced under contract to the Department of Defense. This publication contains a wealth of performance and cost data on military aircraft manufactured from the early 1950's through the early 1980's.

The handbook contains data for 108 individual aircraft, identified by mission (fighter, attack, patrol, bomber etc.), design and series. For example the B-52C is a bomber

(B), 52nd design (52), third series (C). Where successive series of a particular design resulted in virtually indistinguishable aircraft, the handbook combines the series into a single program (e.g., A-7A, A-7B becomes A-7A/B). This reduces the number of distinct aircraft programs to 80.

Since the main concern of this chapter is with the state of the art of technology represented by aircraft, as reflected in performance and capability, it was deemed necessary to reduce the sample to one category of aircraft. The methodology for assigning a performance measure to aircraft relies on a baseline aircraft. To this end the F-4B, used in both fighter and attack missions, has been established as the baseline aircraft. Nineteen aircraft designed for other missions (strategic bombers and patrol) were deleted from the sample. The baseline F-4B is a conventional take-off-and-landing (CTOL) aircraft. Since performance is related to the take-off-and-landing mode, all six vertical and short take-off-and-landing aircraft were also deleted. Finally when successive series of a particular design had the same performance, it was assumed that no extension in technology had been achieved. This resulted in eight later series also being deleted.

The final sample for this portion of the thesis consisted of 47 distinct CTOL fighter and attack aircraft manufactured from the early 1950's through the early 1980's.

Table 2-1 contains a list of the aircraft programs, the prime contractor and the first year of production.

B. MEASURING THE STATE-OF-THE-ART OF TECHNOLOGY

The measures used to reflect technology in this thesis were originally constructed by Analytic Sciences Corporation (ASC) in 1980 and rely on the Gordon and Munson "judgmental weighing approach," as discussed in Chapter I. ASC determined two "figures of merit" for each airplane. An airframe performance (AP) score reflected the performance and capability of the airframe and engine. An aircraft system performance (ASP) score reflected the capability of the airframe, engine and the electronics, navigation and weapons systems, i.e., the complete aircraft. Each score was a judgmentally weighted function of more basic properties.

Airframe performance was measured by the equation:

$$AP = B_1 \times P + B_2 \times R + B_3 \times M + B_4 \times V$$

where

B_i = judgmental weights

P = Payload

R = Range

M = Maneuverability

V = Useful speed

This formulation is an additive multi-attribute utility function. Because values of P, R, M and V were expressed in different units, values for P, R, M and V for individual

TABLE 2-1

SAMPLE AIRCRAFT PROGRAMS, CONTRACTOR AND FIRST YEAR OF PRODUCTION

OBS	PNAME	CONAME	STARTYR
1	A-1J	DOUG	55
2	A-1E/G/H	DOUG	52
3	A-3A/B	DOUG	53
4	A-4C	MCDD	57
5	A-4M	MCDD	70
6	A-4A/B	MCDD	53
7	A-4E/F	MCDD	61
8	A-6A	GRUM	61
9	A-6E	GRUM	70
10	A-7D	VGHT	68
11	A-7E	VGHT	68
12	A-7A/B	VGHT	65
13	A-10A	FAIR	75
14	F-1B/C/M	NOAM	52
15	F/AF-1E	NOAM	54
16	F-2C	MCDN	51
17	F-3A/B/C	MCDN	52
18	F-4E	MCDD	66
19	F-4J	MCDD	66
20	F-4A/B	MCDD	59
21	F-4C/D	MCDD	62
22	F-6A	DOUG	53
23	F-8A/B/C	VGHT	55
24	F-9J	GRUM	55
25	F-9F/H	GRUM	51
26	F-11A	GRUM	53
27	F-14A	GRUM	71
28	F-15A	MCDD	73
29	F-16A	GDYN	78
30	F/A-18A	MCDD	79
31	F-84F	REPB	51
32	F-86D	NOAM	51
33	F-86F	NOAM	51
34	F-86H	NOAM	52
35	F-89C	NRUP	50
36	F-89D	NRUP	51
37	F-100D	NOAM	54
38	F-100A/C	NOAM	52
39	F-101A/B	MCDD	54
40	F-102A	GDYN	53
41	F-104A/B	LOCK	56
42	F-105B/D	REPB	57
43	F-106A/B	GDYN	57
44	F-111A	GDYN	65
45	F-111B	GDYN	66
46	F-111D	GDYN	68
47	F-111F	GDYN	70

aircraft were divided by the corresponding values for the baseline F-4B aircraft. This resulted in all characteristics being expressed as ratios, which could then be combined into an overall score. Weights were determined by the consensus judgement of a large panel of expert operational personnel. Weights were assigned such that the baseline F-4B had an AP score of 10.

Aircraft system performance was measured by the equation:

$$ASP = S\ (B_1 \times P \times U + B_2 \times R \times N + B_3 \times M + B_4 \times V)$$

where

S = Survivability modifier; reflecting susceptibility to detection, identification and destruction.

U = Payload utility modifier; reflecting target acquisition and target engagement capability.

N = Navigation coefficient; reflecting internal navigation system capability.

B_i, P, R, M, V = as previously defined.

Again, values of individual characteristics were scaled by the value for the baseline F-4B aircraft, and expert judgment was relied on for determining the functional form of the utility function.

Individual properties reflected in the models represent "output" measures of performance or capability along distinct dimensions. This is consistent with the work of Knight [Ref. 6] who distinguished between structural and functional technology characteristics as described in

Chapter I. Measures of function or output are therefore used to compare systems of differing structure.

These measures of functional capability can be viewed as indicators of the SOA of technology embodied in the aircraft. Three technology SOA measures to be used in later analysis were defined as follows:

1. Platform (Airframe and Engine) Technology (PLATTECH)=AP;
2. Flyaway Aircraft System Technology (FLYTECH)=ASP;
3. Weapons and Avionics System Technology (SYSTECH)=ASP/AP.

The SYSTECH measure was derived from the two others and was a rough attempt to capture the degree to which the technology in weapon systems and avionic systems enhanced airframe and engine capability to achieve flyaway aircraft system capability. (Dividing ASP by AP is consistent with the idea that the components in the AP formula have been multiplied by weapons and avionics modifiers to arrive at ASP.)

When referring to the three technology measures collectively the expression "TECH" is used. Values of the TECH measures for the 47 aircraft used in this study's sample are contained in Table 2-2.

C. MEASURING EXTENSIONS OF TECHNOLOGY

The TECH variables just described were used to develop measures of the extension in technology represented by

TABLE 2-2

SAMPLE AIRCRAFT TECHNOLOGY MEASURES

OBS	PNAME	PLATTECH	SYSTECH	FLYTECH
1	A-1J	6.57	0.50837	3.34
2	A-1E/G/H	6.57	0.50837	3.34
3	A-3A/B	12.84	0.83645	10.74
4	A-4C	6.22	0.87621	5.45
5	A-4M	7.33	1.16235	8.52
6	A-4A/B	6.84	0.57456	3.93
7	A-4E/F	7.22	1.00693	7.27
8	A-6A	12.13	1.14015	13.83
9	A-6E	12.13	1.84666	22.40
10	A-7D	10.73	1.50699	16.17
11	A-7E	11.59	1.70578	19.77
12	A-7A/B	11.57	1.04581	12.10
13	A-10A	11.03	1.09882	12.12
14	F-1B/C/M	5.90	0.89661	5.29
15	F/AF-1E	6.05	0.89917	5.44
16	F-2C	6.13	0.63785	3.91
17	F-3A/B/C	7.30	1.23562	9.02
18	F-4E	10.17	1.37266	13.96
19	F-4J	10.31	1.29874	13.39
20	F-4A/B	10.31	0.90398	9.32
21	F-4C/D	10.00	1.00700	10.07
22	F-6A	7.60	0.99737	7.58
23	F-8A/B/C	8.40	1.00000	8.40
24	F-9J	4.72	0.85169	4.02
25	F-9F/H	5.00	0.83800	4.19
26	F-11A	6.35	0.91339	5.80
27	F-14A	14.44	2.18213	31.51
28	F-15A	12.11	1.33278	16.14
29	F-16A	11.56	1.35727	15.69
30	F/A-18A	11.60	2.19138	25.42
31	F-84F	7.85	0.65350	5.13
32	F-86D	5.31	0.69303	3.68
33	F-86F	5.09	0.79175	4.03
34	F-86H	6.08	0.93421	5.68
35	F-89C	3.72	0.66129	2.46
36	F-89D	4.72	0.85805	4.05
37	F-100D	6.25	0.95840	5.99
38	F-100A/C	5.51	0.87114	4.80
39	F-101A/B	9.69	1.37771	13.35
40	F-102A	8.02	1.21072	9.71
41	F-104A/B	6.64	1.02259	6.79
42	F-105B/D	11.68	1.27226	14.86
43	F-106A/B	9.58	1.36221	13.05
44	F-111A	15.45	1.19482	18.46
45	F-111B	16.48	1.50546	24.81
46	F-111D	16.48	1.47998	24.39
47	F-111F	16.48	1.88167	31.01

individual aircraft. The approach used was the year-of-technology approach, previously described in Chapter I. Recall that the year-of-technology approach relates technology measures to time to predict an expected year that a system would be produced.[Ref. 3] Differences between the actual year and the expected year are then used as measures of the advance in technology for an individual system.

The analyses presented here used TECH as the dependent variable rather than "time." Since summary technology variables were used rather than many technology characteristics, the summary variables were used as the dependent variable with results that were equivalent but easier to display and discuss.

Results of separately regressing the three TECH variables against the year in which the aircraft were first operational (YEAR) are shown in Table 2-3.

TABLE 2-3
REGRESSION OF TECH ON YEAR

		t-statistic	Significance
PLATTECH = -8.617 + .2971 YEAR		7.011	.0001
Variance explained (R^2):	.5221		
Adjusted R^2:	.5115		
F Value:	49.16		
Model Significance:	.0001		
SYSTECH = -1.038 + .0362 YEAR		7.902	.0001
Variance explained (R^2):	.5812		
Adjusted R^2:	.5719		
F Value:	62.44		
Model Significance:	.0001		
FLYTECH =-30.943 + .7063 YEAR		8.386	.0001
Variance explained (R^2):	.6098		
Adjusted R^2:	.6011		
F Value:	70.32		
Model Significance:	.0001		

In each case, coefficients for YEAR were positive and significant indicators that technology increases with time. The relatively high R^2 values indicate that time explains a large proportion of the technology variance among the aircraft.

The regression equations were used to define three variables reflecting technological complexity or extension:

1. STAND: the average state-of-the-art of technology at the time of production of an aircraft. (For any individual aircraft this is the predicted value for that aircraft from the regression.)

2. ADVANCE: the extension in technology beyond the state of the art. (For any individual aircraft, this is the residual from the regression model, or deviation from the "trend line" for that aircraft.)

3. REACH: the total technology embodied in the system. (For any individual system this is simply STAND + ADVANCE.)

Table 2-4 contains measures of STAND, ADVANCE and REACH for the sample aircraft. The technology measures are broken down into the three technology elements of PLATTECH, SYSTECH, and FLYTECH denoted with the prefixes P, S, and F respectively (hence PSTAND = the STAND of PLATTECH; SADVANCE = the ADVANCE of SYSTEC , and so forth).

There are alternative ways of determining measures of STAND and ADVANCE. Rather than using a "trend line" to reflect the average state of the art of technology, one could designate a specific individual system as a reference point. Candidates for the individual system could be:

TABLE 2-4

SAMPLE AIRCRAFT STAND, ADVANCE AND REACH

PNAME	PSTAND	PADVANCE	PREACH	SSTAND	SADVANCE	SREACH	FSTAND	FADVANCE	FREACH
A-1J	7.7244	-1.1544	6.57	0.95367	-0.44530	0.50837	7.9013	-4.5613	3.34
A-1E/G/H	6.8329	-0.2629	6.57	0.84505	-0.33668	0.50837	5.7825	-2.4425	3.34
A-3A/8	7.1301	5.7099	12.84	0.88126	-0.04481	0.83645	6.4887	4.2513	10.74
A-4C	8.3188	-2.0988	6.22	1.02608	-0.14987	0.87621	9.3138	-3.8638	5.45
A-4M	12.1819	-4.8519	7.33	1.49676	-0.33441	1.16235	18.4951	-9.9751	8.52
A-4A/8	7.1301	-0.2901	6.84	0.88126	-0.30670	0.57456	6.4887	-2.5587	3.93
A-4E/F	9.5074	-2.2874	7.22	1.17090	-0.16398	1.00693	12.1388	-4.8688	7.27
A-6A	9.5074	2.6226	12.13	1.17090	-0.03076	1.14015	12.1388	1.6912	13.83
A-6E	12.1819	-0.0519	12.13	1.49676	0.34990	1.84666	18.4951	3.9049	22.40
A-7D	11.5876	-0.8576	10.73	1.42435	0.08264	1.50699	17.0826	-0.9126	16.17
A-7E	11.5876	0.0024	11.59	1.42435	0.28143	1.70578	17.0826	2.6874	19.77
A-7A/8	10.6961	0.8739	11.57	1.31573	-0.26992	1.04581	14.9639	-2.8639	12.10
A-10A	13.6677	-2.6377	11.03	1.67779	-0.57897	1.09882	22.0264	-9.9064	12.12
F-18/C/M	6.8329	-0.9329	5.90	0.84505	0.05156	0.89661	5.7825	-0.4925	5.29
F/AF-1E	7.4273	-1.3773	6.05	0.91746	-0.01829	0.89917	7.1950	-1.7550	5.44
F-2C	6.5358	-0.4058	6.13	0.80885	-0.17100	0.63785	5.0762	-1.1662	3.91
F-3A/8/C	6.8329	0.4671	7.30	0.84505	0.39057	1.23562	5.7825	3.2375	9.02
F-4E	10.9932	-0.8232	10.17	1.35193	0.02073	1.37266	15.6701	-1.7101	13.96
F-4J	10.9932	-0.6832	10.31	1.35193	-0.05319	1.29874	15.6701	-2.2801	13.39
F-4A/8	8.9131	1.3969	10.31	1.09849	-0.19452	0.90398	10.7263	-1.4063	9.32
F-4C/D	9.8046	0.1954	10.00	1.20711	-0.20011	1.00700	12.8451	-2.7751	10.07
F-6A	7.1301	0.4699	7.60	0.88126	0.11611	0.99737	6.4887	1.0913	7.58
F-8A/8/C	7.7244	0.6756	8.40	0.95367	0.04633	1.00000	7.9013	0.4987	8.40
F-9J	7.7244	-3.0044	4.72	0.95367	-0.10197	0.85169	7.9013	-3.8813	4.02
F-9F/H	6.5358	-1.5358	5.00	0.80885	0.02915	0.83800	5.0762	-0.8862	4.19
F-11A	7.1301	-0.7801	6.35	0.88126	0.03213	0.91339	6.4887	-0.6887	5.80
F-14A	12.4790	1.9610	14.44	1.53296	0.64917	2.18213	19.2014	12.3086	31.51
F-15A	13.0734	-0.9634	12.11	1.60538	-0.27259	1.33278	20.6139	-4.4739	16.14
F-16A	14.5592	-2.9992	11.56	1.78641	-0.42914	1.35727	24.1452	-8.4552	15.69
F/A-18A	14.8564	-3.2564	11.60	1.82261	0.36877	2.19138	24.8515	0.5685	25.42
F-84F	6.5358	1.3142	7.85	0.80885	-0.15534	0.65350	5.0762	0.0538	5.13
F-86D	6.5358	-1.2258	5.31	0.80885	-0.11581	0.69303	5.0762	-1.3962	3.68
F-86F	6.5358	-1.4458	5.09	0.80885	-0.01710	0.79175	5.0762	-1.0462	4.03
F-86H	6.8329	-0.7529	6.08	0.84505	0.08916	0.93421	5.7825	-0.1025	5.68
F-89C	6.2386	-2.5186	3.72	0.77264	-0.11135	0.66129	4.3700	-1.9100	2.46
F-89D	6.5358	-1.8158	4.72	0.80885	0.04921	0.85805	5.0762	-1.0262	4.05
F-100D	7.4273	-1.1773	6.25	0.91746	0.04094	0.95840	7.1950	-1.2050	5.99
F-100A/C	6.8329	-1.3229	5.51	0.84505	0.02609	0.87114	5.7825	-0.9825	4.80
F-101A/8	7.4273	2.2627	9.69	0.91746	0.46025	1.37771	7.1950	6.1550	13.35
F-102A	7.1301	0.8899	8.02	0.88126	0.32947	1.21072	6.4887	3.2213	9.71
F-104A/8	8.0216	-1.3816	6.64	0.98987	0.03272	1.02259	8.6075	-1.8175	6.79
F-1058/D	8.3188	3.3612	11.68	1.02608	0.24618	1.27226	9.3138	5.5462	14.86
F-106A/8	8.3188	1.2612	9.58	1.02608	0.33613	1.362[illegible]1	9.3138	3.7362	13.05
F-111A	10.6961	4.7539	15.45	1.31573	-0.12091	1.19482	14.9639	3.4961	18.46
F-1118	10.9932	5.4868	16.48	1.35193	0.15353	1.50546	15.6701	9.1399	24.81
F-111D	11.5876	4.8924	16.48	1.42435	0.05563	1.47998	17.0826	7.3074	24.39
F-111F	12.1819	4.2981	16.48	1.49676	0.38492	1.88167	18.4951	12.5149	31.01

1. An immediate predecessor system, or

2. the predecessor system with the greatest reach (maximum technology).

The technology embodied in either reference system would constitute STAND, and ADVANCE would be measured as deviations from the specific reference system requiring the reference system to change as time progressed. These two alternatives were tried by Moses with no material enhancement of the analysis.

D. THE MEASUREMENT OF PRODUCTION COST

All cost data for the sample aircraft were taken from the US Military Aircraft Cost Handbook [Ref. 10]. This section describes the steps taken to arrive at a production cost figure for each aircraft that could be considered comparable across the sample. Determination of comparable cost figures were hampered by three factors. First, costs were incurred at different points in time when the value of the dollar differs. Second, aircraft were not purchased singly but rather in "lots" of varying quantity and third, costs tend to decline as additional units are produced due to production "learning."

1. Comparability of Cost Figures

The raw data available consisted of costs and quantities per lot. The following procedures were employed to transform the available data into comparable cost figures:

1. All lot costs were converted to fiscal year 1981 dollars using office of the "Assistant Secretary of Defense, Comptroller" composite price indices for major commodity procurement.

2. Cumulative quantities at the end of each lot were determined by summing the quantities in all preceding lots.

3. Cumulative average costs (FY81) at the end of each lot were determined by summing the costs of all preceding lots and dividing by the cumulative quantities.

4. Learning curves of the following form were fit to the quantity and cumulative average cost series:

$$C_Q = AQ^B$$

where

C_Q = Cumulative average cost for quantity Q.

Q = Cumulative Quantity.

A = Cost of the first unit. (Estimated by the fitting procedure)

B = Constant, estimated by the fitting procedure.

5. The cumulative average cost (CAC) of producing 100 units, CAC (100), was determined by setting Q at 100 and re-entering the learning curve to solve for C_Q.

This procedure was ad hoc but it provided comparable average cost figures at a comparable quantity for all aircraft, taking into consideration the different learning rates experienced on different aircraft programs. The result was an average cost per unit of producing 100 aircraft.

2. Cost Data

Cost data was available in three separate cost categories for each aircraft:

1. Airframe Cost
2. Airframe plus Engine Cost (Platform Cost)
3. Total Flyaway Cost

The approach described above was applied to the three separate cost categories, resulting in three cost variables to be used in the analyses:

1. FRAMCOST: CAC (100) for Airframe cost.
2. PLATCOST: CAC (100) for aircraft Platform cost (Airframe and Engine).
3. FLYCOST: CAC (100) for Flyaway aircraft cost.

Note that there was a direct correspondence between PLATCOST and the previously discussed PLATTECH measure, and between FLYCOST and FLYTECH. In these cases the TECH variables measure technology and the COST variables measure cost for analogously defined components of the aircraft. There was a cost measure for airframes but no TECH measure (without an engine the aircraft can not fly, so no separate measure of airframe performance or technology was possible). As the airframe represents a subset of the Platform, measures for platform technology were used when attempting to explain airframe costs. Although there was a TECH measure for systems there was no analogous COST measure. Technology measures for "systems" were used in some of the tests explaining FLYCOST, however, since the cost of avionics and weapons systems were included in the total flyaway cost.

Table 2-5 contains the COST measures for the aircraft in the sample. Missing historical cost data for some of the sample aircraft resulted in missing COST measures. Accordingly, nine aircraft were deleted from further analysis. Table 2-5 also contains a "SERIES" variable which will be discussed in Chapter III.

TABLE 2-5

SAMPLE AIRCRAFT COST MEASURES

PNAME	FRAMCOST	PLATCOST	FLYCOST	SERIES
A-1J	.	.	.	0
A-1E/G/H	1.212	1.557	1.703	0
A-3A/8	5.136	6.007	7.815	1
A-4C	1.669	1.895	2.100	0
A-4M	2.225	2.927	3.714	0
A-4A/8	1.603	1.859	1.917	1
A-4E/F	1.875	2.436	2.675	0
A-6A	11.286	12.421	13.123	1
A-6E	7.656	8.883	10.846	0
A-7D	2.950	3.847	5.012	0
A-7E	3.901	4.855	5.000	0
A-7A/8	3.217	4.511	5.272	1
A-10A	4.196	5.748	7.272	1
F-18/C/M	2.229	2.297	2.388	1
F/AF-1E	.	.	.	0
F-2C	.	.	.	1
F-3A/8/C	3.419	4.205	4.710	1
F-4E	3.649	4.479	5.919	0
F-4J	3.511	4.416	5.924	0
F-4A/8	7.202	8.802	9.613	1
F-4C/D	.	.	5.753	0
F-6A	.	.	.	1
F-8A/8/C	3.746	4.334	4.475	1
F-9J	.	.	.	0
F-9F/H	0.655	0.856	0.939	1
F-11A	.	.	.	1
F-14A	13.082	17.333	23.901	1
F-15A	10.252	15.446	19.356	1
F-16A	4.045	6.069	9.641	1
F/A-18A	18.854	22.197	23.968	1
F-84F	6.520	6.020	5.943	0
F-86D	0.752	1.118	1.458	0
F-86F	0.887	1.028	1.095	0
F-86H	.	.	.	0
F-89C	.	.	.	0
F-89D	2.471	2.831	3.496	0
F-100D	1.698	2.426	2.659	0
F-100A/C	2.939	3.709	3.856	1
F-101A/8	5.771	6.735	7.291	1
F-102A	6.802	8.125	9.206	1
F-104A/8	2.004	3.830	3.773	1
F-1058/D	10.047	10.952	12.280	1
F-106A/8	7.014	7.897	12.016	1
F-111A	.	.	23.510	1
F-1118	.	.	.	0
F-111D	.	.	24.141	0
F-111F	9.827	14.121	20.897	0

III. PRODUCTION COSTS AND TECHNOLOGY

Chapter II described the procedures for creating both technology measures and cost measures for the various aircraft components. Moses continued his study by relating technology to cost in an attempt to develop cost estimation models. Estimated costs from the models were then compared to actual costs to arrive at measures of cost variance.[Ref 9] His final resulting production cost variance measures are the basis for this thesis' extended examination into cost over/underrun analysis.

A. PRODUCTION COST HYPOTHESES

The initial analysis concerned the association between production cost and the SOA of technology in the aircraft systems produced. Could technology measures reliably predict production costs?

The first hypothesis (H_1) Moses developed was that production costs increase with increases in the SOA of technology (the level of technological complexity). STAND reflects the average technology SOA at the time of production of an aircraft.

H_1: Production Cost is a positive function of STAND.

The second hypothesis (H_2) was that production cost increased with the degree of technological extension of a program. ADVANCE captures this notion.

H_2 : Production Cost is a positive function of ADVANCE.

(REACH is a linear combination of STAND and ADVANCE and hence redundant for testing purposes; it contains no additional information.)

The third hypothesis (H_3) followed from the mixed nature of the sample. The sample includes some aircraft which were the first series of a new design and some which were follow-on series of an existing design. It is reasonable to argue that sufficient production learning would occur during the first series of new design so that follow-on series would experience some reduction in cost. Hence,

H_3 : Production Cost is a positive function of the first series of new design.

Moses created a dummy variable (SERIES) coded "1" for the first series of a new design and "0" for a follow-on series of an existing design. Operationally, the hypotheses imply the following multiple regressions:

FRAMCOST is a positive function of PSTAND, PADVANCE, and SERIES.

PLATCOST is a positive function of PSTAND, PADVANCE, and SERIES.

FLYCOST is a positive function of FSTAND, FADVANCE, and SERIES.

It is important to remember that, since there was no way to break out specific technology measures for the airframe category, measures for the associated platform (including the airframe) were used. This results in the use of

PLATTECH measures for PLATCOST and FRAMCOST and hence both costs are functions of PSTAND and PADVANCE.

B. REGRESSION ANALYSIS OF PRODUCTION COSTS

Regressions using both COST and ln(COST) measures as dependent variables were run. Ln(COST) was used because the natural log reduces the effect of extremes on the regression (particularly important when sample size is small). Findings from using the two alternative measures were similar, but the use of ln(COST), produced higher R^2 values. Those results (models 1-3) are presented in Table 3-1.

All models were highly significant and explained a large proportion of the variance in production cost. All coefficients for the STAND, ADVANCE, and SERIES predictors were also significant and positive, consistent with the three hypotheses concerning production cost. Both the SOA of technology in general and the extension of technology in individual systems seem to provide explanations of production cost. The findings for the SERIES variable indicate an important "premium" in production cost for new designs.

Note that model 2 explained a greater proportion of PLATCOST than model 1 did for FRAMCOST. Since the two models contain the same predictor variables, this result is consistent with PSTAND and PADVANCE being surrogates for frame technology and measuring technology SOA and extension for airframes with "noise".

TABLE 3-1

COST REGRESSIONS - ALL SAMPLE AIRCRAFT

Model	Dependent Variable	Independent Variables	Coeff.	T	Prob.	Model Statistics
1	FRAMCOST	Intercept	-.792	-	-	F = 21.30
	(log)	PSTAND	.206	6.17	.0001	P = .0001
		PADVANCE	.212	5.11	.0001	R^2 = .67
		SERIES	.363	2.07	.0233	Adj. R^2 = .64
2	PLATCOST	Intercept	-.706	-	-	F = 27.71
	(log)	PSTAND	.219	7.36	.0001	P = .0001
		PADVANCE	.198	5.35	.0001	R^2 = .73
		SERIES	.388	2.48	.0094	Adj. R^2 = .70
3	FLYCOST	Intercept	.321	-	-	F = 34.19
	(log)	FSTAND	.099	7.95	.0001	P = .0001
		FADVANCE	.092	5.97	.0001	R^2 = .75
		SERIES	.446	2.96	.0028	Adj. R^2 = .73
4	FLYCOST(alt)	Intercept	.312	-	-	F = 39.94
	(log)	FSTAND	.104	9.84	.0001	P = .0001
		PADVANCE	.189	6.48	.0001	R^2 = .83
		SADVANCE	.589	2.36	.0122	Adj. R^2 = .81
		SERIES	.329	2.55	.0078	

Model 4 in Table 3-1 was an alternative approach to explaining FLYCOST by using the separate ADVANCE measures for platform and systems, the two items making up the flyaway aircraft. (All STAND measures, being predicted values from a regression of TECH on time, are linear transformations of each other. Hence FSTAND is included in model 4.) The basic conclusion to be drawn from model 4 is that additional explanatory ability is achieved by substituting PADVANCE and SADVANCE for FADVANCE.

Each model was also run using REACH in place of STAND and ADVANCE. Although R^2's decreased, all regressions were highly significant indicating that a measure reflecting total technology in systems did well as a substitute for the two separate measures reflecting technology trend plus extension.

C. PRODUCTION COST VARIANCES

Predictions for production cost, given the technology embodied in the aircraft, were created by taking the predicted values from the Table 3-1 regression models (models 1, 2, and 4) and transforming them (un-logging) to arrive at estimated production cost. Actual costs of course differ from the estimated costs so variances were constructed by subtracting estimated costs from actual costs (actual - estimated). These cost variance measures are not measures of cost overruns or underruns in the most traditional sense of costs being measured relative to a budget. Traditional variance measures most frequently compare resource inputs (costs) relative to budgeted inputs. The variance measures here compare actual costs with expected costs based on output, where output is measured by the technological performance of the aircraft. The cost variance measures resulting here are interpreted as cost over/underruns, given the actual cost incurred to achieve a level of technology versus the expected cost for that level of technology.

Table 3-2 lists the actual costs.(COST), estimated costs (EST) and cost variances (VAR) for the various cost categories. The variances may be interpreted as measures of cost overruns or cost savings, relative to the technology embodied in the systems.

D. SUMMARY

Using techniques established through archival research and cost estimation work performed by Moses, production cost variances for 38 individual aircraft have been obtained. The prior work has established measures of technology and their related expected cost of production. Moses has established the variances from expected costs in three categories for each of the 38 aircraft. The process of examining relationships between production cost variances and a firm´s financial data can now be initiated.

TABLE 3-2

AIRCRAFT COSTS, ESTIMATED COSTS AND COST VARIANCES

	AIRFRAME			PLATFORM			FLYAWAY		
	(COST)	(EST)	(VAR)	(COST)	(EST)	(VAR)	(COST)	(EST)	(VAR)
A-1J	.	1.7354	.	.	2.1278	.	.	1.9168	.
A-1E/G/H	1.212	1.7455	-0.5335	1.557	2.0889	-0.5319	1.703	1.9417	-0.2387
A-3A/B	5.136	9.4677	-4.3317	6.007	10.7262	-4.7192	7.815	10.6813	-2.8663
A-4C	1.669	1.6051	0.0639	1.895	2.0100	-0.1150	2.100	2.2091	-0.1091
A-4M	2.225	1.9808	0.2442	2.927	2.7128	0.2142	3.714	3.0508	0.6632
A-4A/B	1.603	2.6529	-1.0499	1.859	3.2692	-1.4102	1.917	2.9393	-1.0223
A-4E/F	1.875	1.9690	-0.0940	2.436	2.5112	-0.0752	2.675	2.8342	-0.1592
A-6A	11.286	8.0200	3.2660	12.421	9.7899	2.6311	13.123	10.7900	2.3330
A-6E	7.656	5.4811	2.1749	8.883	7.0180	1.8650	10.846	11.3311	-0.4851
A-7D	2.950	4.0890	-1.1390	3.847	5.2537	-1.4067	5.012	7.1770	-2.1650
A-7E	3.901	4.9069	-1.0059	4.855	6.2291	-1.3741	5.000	9.4962	-4.4962
A-7A/B	3.217	7.0675	-3.8505	4.511	8.9808	-4.4698	5.272	9.0227	-3.7507
A-10A	4.196	6.1827	-1.9867	5.748	8.5826	-2.8346	7.272	8.0499	-0.7779
F-1B/C/M	2.229	2.1777	0.0513	2.297	2.6973	-0.4003	2.388	2.9872	-0.5992
F/AF-1E	.	1.5572	.	.	1.9078	.	.	2.1965	.
F-2C	.	2.2909	.	.	2.8057	.	.	2.6903	.
F-3A/B/C	3.419	2.9304	0.4886	4.205	3.5590	0.6460	4.710	4.7552	-0.0452
F-4E	3.649	3.6452	0.0038	4.479	4.6447	-0.1657	5.919	6.0153	-0.0963
F-4J	3.511	3.7550	-0.2440	4.416	4.7752	-0.3592	5.924	5.9135	0.0105
F-4A/B	7.202	5.4733	1.7287	8.802	6.7439	2.0581	9.613	6.7090	2.9040
F-4C/D	.	3.5433	.	.	4.3817	.	5.753	4.7770	0.9760
F-6A	.	3.1168	.	.	3.8002	.	.	4.3548	.
F-8A/B/C	3.746	3.6788	0.0672	4.334	4.5077	-0.1737	4.475	5.0313	-0.5563
F-9J	.	1.1723	.	.	1.4751	.	.	1.6533	.
F-9F/H	0.655	1.8028	-1.1478	0.856	2.2431	-1.3871	0.939	2.4442	-1.5052
F-11A	.	2.3911	.	.	2.9669	.	.	3.2711	.
F-14A	13.082	12.8392	0.2428	17.333	16.4507	0.8823	23.901	29.5799	-5.6789
F-15A	10.252	7.8038	2.4482	15.446	10.4991	4.9469	19.356	11.4349	7.9211
F-16A	4.045	6.8782	-2.8332	6.069	9.7101	-3.6411	9.641	10.2310	-0.5900
F/A-18A	18.854	6.9235	11.9305	22.197	9.8477	12.3493	23.968	16.7833	7.1847
F-84F	6.520	2.2941	4.2259	6.020	2.6750	3.3450	5.943	2.7068	3.2362
F-86D	0.752	1.3388	-0.5868	1.118	1.6176	-0.4996	1.458	1.7129	-0.2549
F-86F	0.887	1.2778	-0.3908	1.028	1.5487	-0.5207	1.095	1.7415	-0.6465
F-86H	.	1.5732	.	.	1.8957	.	.	2.2747	.
F-89C	.	0.9575	.	.	1.1734	.	.	1.2495	.
F-89D	2.471	1.1814	1.2896	2.831	1.4393	1.3917	3.496	1.6884	1.8076
F-100D	1.698	1.6247	0.0733	2.426	1.9849	0.4411	2.659	2.3624	0.2966
F-100A/C	2.939	2.0049	0.9341	3.709	2.4968	1.2122	3.856	2.7333	1.1227
F-101A/B	5.771	4.8455	0.9255	6.735	5.7839	0.9511	7.291	8.0596	-0.7686
F-102A	6.802	3.407[illegible]	3.3949	8.125	4.1297	3.9953	9.206	5.3472	3.8588
F-104A/B	2.004	2.528[illegible]	-0.5241	3.830	3.2009	0.6291	3.773	3.6381	0.1349
F-105B/D	10.047	7.3465	2.7005	10.952	8.7374	2.2146	12.280	10.8976	1.3824
F-106A/B	7.014	4.7065	2.3075	7.897	5.7648	2.1322	12.016	7.7213	4.2947
F-111A	.	16.0901	.	.	19.3641	.	23.510	20.5358	2.9742
F-111B	.	13.8927	.	.	16.2039	.	.	21.4824	.
F-111D	.	13.8393	.	.	16.4047	.	24.141	20.9804	3.1606
F-111F	9.827	13.7861	-3.9591	14.121	16.6080	-2.4870	20.897	26.3578	-5.4608

IV. HYPOTHESIS DEVELOPMENT

This chapter will discuss the concept of developing systematic associations between a firm's financial condition and its production cost control as a step toward predicting a firm's future cost overruns or cost underruns. The chapter consists of four distinct steps:

1. The first step describes the basic hypotheses: How production cost may be a function of a firm's production capability and how production capability relates to financial condition.

2. The second step discusses the measurement of financial condition through the use of commonly available financial data. This step also discusses how financial data can be grouped into five distinct aspects of financial condition and how these aspects relate to future production costs.

3. The third step discusses the use of financial ratios, calculated from accounting data contained in financial reports, to represent the aspects of financial condition previously described and identifies the specific ratios used in the analysis.

4. The fourth step describes a method to help narrow the range of ratios to be used in the analysis.

A. BASIC HYPOTHESIS

Utilizing the technology and cost measures established in Chapters II and III, if a contractor can produce a certain level of technology for less money than predicted, then the contractor has achieved what is termed a "cost underrun." If a contractor produces that level of technology for more money than predicted then the term "cost overrun" applies. This underrun/overrun concept does not necessarily indicate whether or not the contractor has made or lost money on the production, but rather whether the **production cost** was more than it should have been, for the level of technology embodied in the product.

This chapter is based on the premise that a logical way to examine a firm's ability to produce something is to look at the firm's past and/or current financial condition, as measured by data provided in published financial statements (including balance sheet and income statement information). Financial relationships that may influence future production will be examined with the intent of identifying any quantifiable patterns.

To examine whether a company will overrun or underrun expected costs in this context is to ask how much will production efficiency and capability be affected by the firm's financial position. The focus in developing specific hypotheses will be to determine the financial elements that may tend to influence production output, production capabilities and limitations, and general production efficiencies.

Production cost may be related to production time. If a production effort takes longer than expected this added time will likely lead to added costs. Consequently, aspects of financial condition that may affect the time to complete a production effort may also be related to cost overruns or cost underruns.

An initial model will be developed and presented in Chapter VI. The goal of producing the model is to help predict what financial factors of a prospective contractor will signal the likelihood of overrunning or underrunning predicted production costs. In other words: what financial factors would tend to indicate a firm´s propensity to experience production cost overruns or underruns?

B. ASPECTS OF FINANCIAL CONDITION

What financial aspects would tend to signal future production capabilities, limitations or efficiencies? It is possible to categorize financial data in many ways. However, several finance and accounting references categorize financial data into broad categories or aspects of financial condition. In particular, the work involved in two studies was used extensively [Refs. 11 and 12]. The financial aspects identified in those two studies will be adopted for this thesis and are as follows:

1. **Profitability** (return on investment)
2. **Short-term liquidity**
3. **Solvency** (capital structure)
4. **Activity** (efficiency or turnover)
5. **Capital goods investment**

It is reasonable to suggest that production costs, and hence cost overruns and underruns, may depend on these five aspects of financial condition. Examining these five aspects of financial condition for individual firms relative to other firms in the same industry may help to explain an individual firm´s propensity towards production cost overruns or underruns prior to a contract being awarded.

Why financial condition may be related to cost control and suggestions on the nature of the associations expected to be observed will be discussed in the next sections. Potential relationships between traditional balance sheet and income statement financial data and their influence on production costs will also be discussed.

1. **Profitability Aspect**

The objective of this thesis is to determine if a firm can meet production time and cost elements, based on a projected "standard" for the technology embodied in the product. On the surface a firm´s profitability may not seem to relate to the production cost overrun/underrun concepts. However, because profits are a prime motivator of most firms, it is plausible to argue that the goal of higher profits may influence a firm´s actions down to the level of production techniques and efficiencies including their related costs.

Examining what profits actually represent may shed some light on their influence over production costs.

Profits are commonly defined as the difference between revenue and expenses.

Two obvious avenues leading towards higher profits are low expenses or high revenues. While neither avenue is inherently more effective in enhancing profitability, it can be argued that raising revenue relative to expenses is more important than reducing expenses relative to physical output.[Ref. 13: p. 50]

As Gold implied [Ref. 15: p. 204] management´s efforts to increase the rate of profits on total investment often does not concentrate on cost-reducing innovations if this leads to reductions in product prices and capacity utilization. Instead, offsetting higher unit costs by increased capacity utilization and higher product prices might be more attractive to a firm´s management. By this logic a typical firm´s goal of high profitability may lead to higher total prices to the buyer rather than cost reducing innovations. High profits are normally seen as a positive element in a firm´s financial profile (investors, shareholders, and management normally desire high profits) and are often a stated goal of management. However, an abnormally high profit return may also depict an undercapitalized situation,[Ref. 14: p. 82] giving rise to only short-term high profits and inefficiencies in later periods.

These views seem to imply that high profits may relate directly to higher costs for the buyer. These concepts lead to the first element of the hypothesis: **high profits are likely to indicate cost overruns.** This logic would also seem to indicate that low profits should be associated with production cost underruns.

2. Short Term Liquidity Aspect

Short term liquidity reflects a firm´s ability to meet short term financial obligations. This aspect is a major concern to suppliers and creditors of a firm producing a product that is technologically challenging.

New and updated products may require substantial outlays to finance inventories and production start-up costs. A critical concern in meeting any production schedule is the availability of raw materials and inventory. The probable perception by a firm´s suppliers of greater risk of default, may indicate **firms with poor short term liquidity may be more likely to suffer inventory delays and higher costs** (less attractive payment/credit terms) **with resulting cost overruns.** These added costs translate directly into a tendency towards cost overruns.

Additionally, liquidity is typically associated with flexibility. Firms with sufficient liquid resources are in a better position to respond to evolving opportunities or changes in their environment. Liquid resources provide slack, or a buffer, against unexpected contingencies.

Flexibility to respond to its environment may permit a firm to better control its ongoing operations. This increased control may be reflected in better control over costs.

3. Solvency Aspect

Solvency indicates a firm´s ability to meet long-term obligations, both financial and operational. This is the "risk" of the contractor´s capital structure and debt repayment ability. Solvency captures the relationship of long-term debt to various assets or debt expense (interest) to the resources available to pay the expense.

The aviation production industry is structured around long-term production schedules and commitments. A firm experiencing high financial/debt risk as a result of poor solvency may be more constrained in production capacity due to the high cost of capital goods financing. This constraint in the acquisition of capital goods may reduce the firm´s flexibility in production and may even <u>require</u> higher product prices to recover from or stay abreast with high debt costs. **It is therefore expected that less solvent firms will have a tendency toward cost overruns.**

A firm that is solvent would present a good debt repayment history to creditors,which may contribute to easier credit and lower debt costs (interest rates) in the future. Lower long-term debt costs may allow the firm the flexibility and resources to invest in plant and equipment at a favorable rate. Thus solvent firms have a second possible benefit: favorable debt costs may allow the firm to modernize plant and equipment while keeping debt costs to a minimum, and modern equipment is usually more efficient than older equipment. This argument, complementary to the one above, supports the hypothesis that one **indicator of a possible cost underrun may be a firm with good solvency.**

4. Activity (Efficiency or Turnover) Aspect

"Activity" relates the amount of resources generated during a period (sales) with assets available to generate sales. By the very nature of this financial aspect we get some measure of a specific asset´s operational (turnover) efficiency. This aspect shows the degree to which resources or capacity are being fully utilized.

It might be argued that firms efficiently utilizing their resources to their maximum potential will be more likely to accurately predict and deliver on a challenging production schedule. This seems reasonable for strong firms, therefore, for activity the hypothesis is that the more efficient a firm, the more likely the firm is to meet production cost projections. Therefore **high activity/efficiency ratios should be associated with production cost underruns.** Using the same logic, firms with low efficiency/ activity ratios are hypothesized to be more likely to experience production cost overruns.

5. Capital Goods Investment Aspect

Capital goods investment is the largest single asset on the books for most large manufacturing corporations.[Ref 14: p. 29] It is therefore reasonable to expect efficient and competitive firms to continuously invest in capital goods to both offset depreciation and to keep up with modern manufacturing techniques. This implies that major investment in capital goods is a constant requirement. Outdated or inefficient production facilities may increase costs and result in cost overruns.

Low investment or declining investment over time might indicate a stagnation of production technology. This could be the result of a lack of funds to invest or unresolved technical difficulties in the production process. Such difficulties might entice management to avoid procurement of plant and equipment until it is certain that plant and equipment will meet technological specifications for the product. In any event low **capital goods investment are likely to be an indicator** of future production limitations/inefficiencies and this is considered to be an indicator of **potential overruns**.

Although it can also be argued that more modern equipment has more capacity and efficiency [Ref. 13: p. 168], and therefore may require less investment to maintain capacity it is also likely that new, "more efficient" equipment will cost more than what it replaces. Thus, because of the nature of the industry in the sample, continuous enhancements in the technological sophistication of the output would likely require constant update and replacement of production equipment. Relatively low capital investment would tend to indicate conditions leading to production limitations in this high-tech environment and hence future cost overruns.

6. Financial Aspects Summary

A quick summary of the five hypotheses concerning aspects of financial condition is presented below:

Financial Aspect	Condition as compared to industry sample	Expected relation to overrun/underrun
Profitability	Low	cost underrun
	High	cost overrun
Short Term Liquidity	Low	cost overrun
	High	cost underrun
Solvency	Low	cost overrun
	High	cost underrun
Activity	Low	cost overrun
	High	cost underrun
Capital Goods Inv.	Low	cost overrun
	High	cost underrun

C. RATIOS AS THE BUILDING BLOCKS OF FINANCIAL ASPECTS

The hypotheses outlined above are specified in terms of the relationship between <u>aspects</u> of financial condition and production cost. To test the hypotheses, measures of the financial aspects are necessary. The objective of this section is to establish financial ratios that will serve as reasonable measures of the aspects of financial conditions previously discussed.

Financial ratio analysis is a common analytical tool for observing and understanding the condition of a firm. While financial ratio analysis is common, this thesis' objective in looking at financial ratios is somewhat non-traditional. Most treatments of ratio analysis presume that the objective is to assess the future profitability or risk of a firm. The present concern with ratio analysis is more narrowly focused. The concern here is with ratios as indicators of conditions that may influence production timeliness, effectiveness or efficiency and consequently have some association with cost overruns and cost underruns.

Numerous ratios can be calculated from balance sheet and income statement information and analysts can justify grouping these ratios in many different ways. Financial ratios calculated from accounting data contained in financial reports for contractors will be used to represent the factors or aspects of financial condition. The 25 ratios to be used in the analysis are presented in Table 4-1, grouped into the five financial aspects developed above. The positive/negative signs reflect the hypothesized association of each ratio with the cost variance measures developed in Chapter III. Observing associations consistent

TABLE 4-1
LIST OF RATIOS

Ratio Name	Calculation	Hypothesized Association of Ratio with Cost Variance
(PROFITABILITY ASPECT)		
1.Return on Assets	Net Income/Total Assets	+
2.Return on Equity	Net Income/S.H. Equity	+
3.Return on Capital	Net Income / Non-Curr. Liab + S.H. Equity	+
4.Profit Margin	Net Income/Sales	+
5.Gross Margin	Gross Margin/Sales	+
(LIQUIDITY ASPECT)		
6.Current Ratio	Curr. Assets/Curr. Liab.	-
7.Quick Ratio	(Cash + Mkt Sec. +Acct. Rec.) / Curr. Liab.	-
8.Rec's to Working Cap.	Receivables / Curr. Assets-Curr. Liab.	-
9.Working Cap. Ratio	(Curr. Assets - Curr. Liab.) / Total Assets	-
10.Receivables Turnover	Sales/Accounts Receivable	-
(SOLVENCY ASPECT)		
11.Debt Ratio	Total Liab./Total Assets	-
12.Debt to Equity	Total Liab./S.H. Equity	-
13.Curr. Debt Ratio	Curr. Liab./Total Assets	-
14.Non-Curr. Debt Ratio	Non-Curr. Liab./Total Assets	-
15.Interest Coverage	Operating Income/Interest Exp.	+
16.Debt to Plant Equip.	Total Liab./Plant & Equip	-
(ACTIVITY/EFFICIENCY ASPECT)		
17.Asset Turnover	Sales/Total Assets	-
18.Plant Asset Turnover	Sales/Plant & Equip.	-
19.Inventory Turnover	Cost of Goods Sold/Inventory	-
20.Working Cap. Turnover	Sales/(Curr. Assets-Curr. Liab)	-
(INVESTMENT ASPECT)		
21.Investment to Sales	Investment/Sales	-
22.Investment to Funds	Investment/(Net Income + Dep.)	-
23.Investment to Assets	Investment/Total Assets	-
24.Investment to Plant	Investment/Plant & Equipment	-
25.Investment to Dep.	Investment/Depreciation Exp.	-

- indicating lower costs + indicating higher costs with these signs imply support for the hypothesized relationships between financial aspects and cost over/under runs.

Although many more ratios can be calculated from data available from income statements and balance sheets, the 25 ratios presented are felt to be sufficiently comprehensive to represent the five aspects of financial condition without being cumbersome.[1]

D. RATIO ANALYSIS CONSOLIDATION

Borrowing some ideas put forth by Kung H. Chen and Thomas A. Shimerda [Ref. 16] it can be expected that, since various ratios have been selected to represent the specific financial aspects, these ratios may be highly correlated. It is reasonable to suspect that one ratio can represent each of these financial aspects and can account for most of

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[1]. Work done by Lev [Ref. 11] addresses the use of ratios categorized into financial aspects. Four of the five categories discussed above use portions of his approach.

Work done by McGrath and Moses [Ref. 12] groups many of the same ratios into the same five aspects used here.

In chapter 2 of Millers´ text [Ref. 14], Miller discusses nine ratios that measure "...important information about the financial structure and competitive position of a firm..."[Ref. 14: p. 29] The nine ratios Miller discusses are also used in this thesis and are: Return on Equity, Current Ratio, Receivables to Stockholder´s Equity, Working Capital Ratio, Debt to Equity Ratio, Current Debt Ratio, Long-term Debt Ratio, Fixed Asset Turnover, and Working Capital Turnover.

The ratio of "Debt to Plant Equipment" is not a common ratio but it may reflect an important aspect of analysis when looking for a measure of solvency and capital goods structure in one element, particularly for what is perceived as an industry heavily reliant on plant and equipment to maintain technological competitiveness in the industry.

the information provided by all the ratios within that category.[Ref. 16: p. 53] Chen and Shimerda conclude that more than one ratio from a particular category leads to "multicollinearity among ratios and distorts the relationship between the dependent and independent variables."[Ref. 16: p. 59] It is therefore logical to select a small number of ratios from each category when performing tests (Chen and Shimerda recommend one ratio from each category in most cases).

Chen and Shimerda did not put forward a method to select the ratio with the most sensitivity to the financial aspect being evaluated. Therefore the final task in this chapter is to select the "most" representative ratio(s) from each financial aspect to use as an indicator for that aspect in the multiple regression analysis reported upon in the next chapter. Miller also asserts that there are ratios that have shown themselves to be more representative than others [Ref. 14: p. 15] (even though Miller´s analysis centered around the more traditional use of ratio analysis in assessing the profitability and risk of a firm).

E. KEY RATIOS AS A MEASURE OF FINANCIAL ASPECTS

The following sections offer arguments for using a particular ratio as most representative of the aspect of financial condition it is grouped under. The choice of the ratios attempts to consider both the nature of the industry in the sample (military aircraft producers) and the nature of the relationships between financial condition and cost control technique under examination.

1. Profitability

Miller asserts that "Profit Margin" is a primary, or causal ratio. He states, roughly: The more pennies of profit per dollar of sales, the greater the opportunity for growth.[Ref. 14: p. 91] As the profit margin ratio is traditionally one of the strongest indicators of profit it may also be most representative of the profitability aspect of financial condition.

2. Liquidity

Evaluation of efficiencies and capabilities in a long-lead-time manufacturing arena with large capital investment requirements suggests a broad view of liquidity including all major assets, vice just "current" or "quick" assets. A comparison of working capital (current assets less current liabilities) to <u>total</u> assets, may be the most representative ratio of liquidity. This rationale leads to the choice of the "Working Capital Ratio" as the most representative ratio for the liquidity aspect.

3. Solvency

Again, because of the nature of the industry being examined, a broad solvency perspective is probably more indicative of a firms' long-term business prospective. By looking at all liabilities versus all assets in the traditional "Debt Ratio" one of the broadest views of solvency is obtained.

4. Activity

For activity it may be desirable to emphasize the asset that is hypothesized to be the most representative or indicative of efficiency in the aerospace industry. Since plant and equipment has already been described as an important asset for the aerospace industry, a ratio utilizing this measure is expected to be indicative of capitalization, and plant and equipment competitiveness. It may therefore be expected that the ratio of a firm's sales to its plant and equipment (the Plant Asset Turnover Ratio) may best reflect the level of plant and equipment efficiency and be the most representative ratio of activity for the sample.

5. Investment

Using a somewhat different approach to P&E may be important given the earlier hypothesis concerning the effect of plant and equipment on efficiency and production capabilities. The somewhat less traditional "Investment to Depreciation" may be a good indicator of the extent to which dollars are applied to replacing, modernizing or supplementing plant and equipment capacity. The ratio of investment to depreciation reflects the degree to which an individual firm appears to be compensating for asset usage through new investment. Hopefully, investment in plant and equipment is always at least what depreciation is over time.

F. SUMMARY

Five financial aspects that represent the financial conditions of a manufacturing firm have been discussed. Hypotheses linking these five aspects to cost have been presented. To measure these five aspects 25 financial ratios, developed from common financial data, have been grouped into the five aspects. In an attempt to reduce possible intercorrelation problems between the ratios, arguments for those ratios that may be the most representative of each aspect have been proposed. The five financial aspects and the ratios hypothesized to be most representative of each aspect are listed below:

1. **Profitability Aspect**: Profit Margin Ratio.
2. **Liquidity Aspect**: Working Capital Ratio.
3. **Solvency Aspect**: Debt Ratio.
4. **Activity Aspect**: Plant Asset Turnover Ratio.
5. **Investment Aspect**: Investment to Depreciation Ratio.

The goal of the next chapter will be to report the results of tests of hypotheses presented here. It will include tests relating the financial ratios of aerospace firms to the previously determined measures of production performance (cost overruns or underruns).

V. CALCULATION AND ANALYSIS OF RATIO VARIABLES

The purpose of this chapter is to describe the analyses of hypotheses concerning cost variances and their association to financial ratios. The analyses conducted are an evolutionary process progressing from simple univariate plots and correlation, through multi variate regressions of the financial ratios previously discussed. The hypotheses concerning relationships between financial data and production costs will be tested for measures of cost control based on the three specific measures of cost established in Chapter III:

1. Airframe Cost Variances
2. Platform Cost Variances (Airframe and Engine Cost)
3. Flyaway Cost Variances (Total Aircraft Cost including Avionics)

The following sections discuss the data set, regression variable selection, and outlier data considerations followed by a review and presentation of the "cleaned" data.

A. DATA SET

As described in Chapter III, a sample of 38 individual aircraft resulted from the scope limitations applied. Financial information available from annual company balance sheets and income statements served as the source of data used to compute the financial ratios. Of the 38 aircraft, two had insufficient financial data available to be included, so the final sample consists of 36 aircraft from the 1950's through the 1980's. To perform the various analyses desired the data must be segregated into "dependent" and "independent" variables.

1. Dependent Variable Selection

The dependent variables are cost variances, one for each of the three categories of aircraft cost, determined in Chapter III. They are the difference between the expected and predicted costs, given the technology embodied in each aircraft. The three dependent variables are airframe cost variance (FRAMVAR), platform cost variance (PLATVAR), and total flyaway aircraft cost variance (FLYVAR).

2. Independent Variable Selection

The selection of independent variables was discussed in Chapter IV. The 25 financial ratios serve as the independent variables to be used in examining relationships with production cost variances. Table 5-1 lists the independent variables and the labels used in denoting them throughout the remainder of this thesis.

The objective of the thesis is to identify indicators of potential cost over/underruns that exist <u>prior</u> to the start of production. Consequently, the financial ratios were measured in the year immediately prior to the first year of production. Throughout the remainder of the chapter, the ratio labels are followed by "1" indicating their measurement one year before production. Some tests were conducted using ratios measured two years prior to production. Results from using those ratios were generally less satisfactory. Hence this chapter concentrates on the findings from ratios measured just one year prior to production start.

TABLE 5-1
INDEPENDENT VARIABLES AND LABELS

VARIABLE NAME	LABEL	VARIABLE NAME	LABEL
Return on Assets..	ROASS	Interest Coverage..	INTCOV
Return on Equity..	ROEQ	Debt to Plant and Equipment....	DET2PE
Return on Capital.	ROCAP	Asset Turnover.....	ASSTRN
Profit Margin.....	PROFMAR	Plant Asset Turnover.........	PATRN
Gross Margin......	GROMAR	Inventory Turnover.........	INVTRN
Current Ratio.....	CURRAT	Working Capital Turnover.........	WCAPTRN
Quick Ratio.......	QUIRAT	Investment to Sales............	NVS2SAL
Receivables to Working Capital.	REC2WC	Investment to Funds............	NVS2FUN
Working Capital Ratio...........	WCAPRAT	Investment to Assets...........	NVS2ASS
Receivables Turnover........	RECTRN	Investment to Plant............	NVS2P
Debt Ratio........	DETRAT	Investment to Depreciation.....	NVS2DEP
Debt to Equity....	DET2EQ		
Current Debt Ratio...........	CDETRAT		
Non-Current Debt Ratio......	NCDETRAT		

Tables 5-2 through 5-4 present values for the ratios for the sample in the year prior to production.

TABLE 5-2

RATIO DATA FOR ONE YEAR PRIOR TO PRODUCTION
(Ratios 1 - 8)

OBS	PNAME	ROASS1	ROEQ1	ROCAP1	PROFMAR1	GROMAR1	CURRAT1	QUIRAT1	REC2WC1
1	A-1E/G/H	0.040163	0.084767	0.084767	0.0307000	0.134600	1.54757	0.47013	0.39596
2	A-3A/B	0.043461	0.123147	0.123147	0.0206000	0.099700	1.30597	0.43781	0.71138
3	A-4C	0.090720	0.243087	0.215055	0.0362559	0.159621	1.41021	0.54590	0.93858
4	A-4M	0.077049	0.204985	0.134247	0.0388915	0.085290	1.24262	0.28623	1.06242
5	A-4A/B	0.067492	0.232915	0.149917	0.0374833	0.178327	1.31564	0.64734	1.60498
6	A-4E/F	0.085530	0.191229	0.188851	0.0276602	0.142745	1.45383	0.38724	0.78679
7	A-6A	0.068005	0.134051	0.126020	0.0220976	0.066517	1.66660	0.77205	0.81829
8	A-6E	0.059037	0.139835	0.094602	0.0187071	0.042616	1.77877	1.09716	1.34261
9	A-7D	0.038481	0.138143	0.075249	0.0181129	0.121769	1.71409	0.88143	0.74898
10	A-7E	0.038481	0.138143	0.075249	0.0181129	0.121769	1.71409	0.88143	0.74898
11	A-7A/B	0.038616	0.171662	0.074770	0.0151862	0.034095	1.61576	1.03682	1.35675
12	A-10A	0.040431	0.100167	0.063425	0.0237718	0.181062	1.80705	0.65677	0.61609
13	F-18/C/M	0.056300	0.119099	0.119099	0.0361390	0.086309	1.69073	0.74317	0.77676
14	F-4E	0.053854	0.143025	0.094490	0.0276453	0.061932	1.56878	0.46002	0.66637
15	F-4J	0.053854	0.143025	0.094490	0.0276453	0.061932	1.56878	0.46002	0.66637
16	F-4A/B	0.065811	0.221638	0.175659	0.0226669	0.106400	1.27125	0.48897	1.73192
17	F-4C/D	0.097742	0.167568	0.165223	0.0351584	0.162625	1.98352	0.60391	0.48960
18	F-8A/B/C	0.098893	0.173476	0.169392	0.0395480	0.221102	1.69174	1.74679	0.62334
19	F-14A	0.052482	0.120977	0.080174	0.0204390	0.044100	1.97498	1.04144	0.97033
20	F-15A	0.047067	0.133907	0.113919	0.0409714	0.205470	1.30625	0.11678	0.34736
21	F-16A	0.004747	0.010370	0.007406	0.0026196	0.066214	1.28608	0.27105	0.73279
22	F/A-18A	0.052030	0.134356	0.126382	0.0390286	0.177808	1.36067	0.49174	0.46866
23	F-84F	0.085852	0.233486	0.172600	0.0415851	0.112852	1.50335	0.77680	0.67152
24	F-86D	0.120782	0.156146	0.156146	0.0565328	0.116345	2.08560	1.64991	0.25128
25	F-86F	0.120782	0.156146	0.156146	0.0565328	0.116345	2.08560	1.64991	0.25128
26	F-89D	-0.003435	-0.016667	-0.006164	-0.0010274	0.063927	2.01754	0.97702	0.08431
27	F-100D	0.059920	0.196323	0.196323	0.0201248	0.069141	1.32650	0.70188	1.26724
28	F-100A/C	0.056300	0.119099	0.119099	0.0361390	0.086309	1.69073	0.74317	0.77676
29	F-101A/B	0.086055	0.253184	0.184039	0.0317080	0.141533	1.28789	0.67076	1.91725
30	F-102A	0.076236	0.183792	0.163285	0.0365438	0.077458	1.64382	0.96789	0.58021
31	F-104A/B	0.057860	0.177984	0.120810	0.0256867	0.051076	1.51697	0.93212	0.80657
32	F-105B/D	0.075453	0.159476	0.155849	0.0213741	0.048854	1.67355	1.29267	1.25449
33	F-106A/B	0.073193	0.193397	0.144230	0.0329562	0.062871	1.62506	0.96072	1.18281
34	F-111A	0.068390	0.142213	0.108573	0.0269713	0.050539	1.88549	1.32552	1.16868
35	F-111D	0.061930	0.169592	0.116827	0.0252962	0.056539	1.38372	0.35868	0.73293
36	F-111F	0.002345	0.007610	0.004822	0.0009965	0.022242	1.29881	0.27689	0.73105

TABLE 5-3

RATIO DATA FOR ONE YEAR PRIOR TO PRODUCTION (Ratios 9 - 17)

OBS	PNAME	WCAPRAT1	RECTO1	DETRAT1	DET2EQ1	CDETRA1	NCDETRA1	INTCOV1	DET2PE1	ASSTRN1
1	A-1E/G/H	0.288126	11.4671	0.526193	1.11057	0.526193	0.000000	23.0000	3.43726	1.30824
2	A-3A/B	0.197988	14.9792	0.647082	1.83352	0.647082	0.000000	7.7143	5.18710	2.10975
3	A-4C	0.237167	11.2408	0.626801	1.67953	0.626801	0.048645	29.5000	3.66756	2.50220
4	A-4M	0.104960	17.7662	0.630675	1.67788	0.630675	0.198061	11.2000	3.47886	1.98113
5	A-4A/B	0.173532	6.4650	0.710230	2.45101	0.710230	0.160426	6.3175	2.68557	1.80059
6	A-4E/F	0.248289	15.8286	0.552735	1.23581	0.552735	0.005633	12.0269	2.76591	3.09216
7	A-6A	0.303865	12.3766	0.492698	0.97121	0.492698	0.032329	11.0847	2.10293	3.07746
8	A-6E	0.278610	8.4367	0.559626	1.32552	0.559626	0.201872	4.1660	1.56311	3.15588
9	A-7D	0.300911	9.4264	0.721444	2.58994	0.721444	0.232821	1.8584	3.45312	2.12448
10	A-7E	0.300911	9.4264	0.721444	2.58994	0.721444	0.232821	1.8584	3.45312	2.12448
11	A-7A/B	0.279338	6.7095	0.775046	3.44535	0.775046	0.291507	1.5545	4.88925	2.54284
12	A-10A	0.293127	9.4179	0.597035	1.47913	0.597035	0.233827	1.4286	3.72269	1.70081
13	F-18/C/M	0.364209	5.5067	0.527286	1.11545	0.527286	0.000000	26.5331	4.85956	1.55787
14	F-4E	0.244609	11.9512	0.623466	1.65580	0.623466	0.193409	5.5977	3.88292	1.94803
15	F-4J	0.244609	11.9512	0.623466	1.65580	0.623466	0.193409	5.5977	3.88292	1.94803
16	F-4A/B	0.169626	9.8829	0.703070	2.36780	0.703070	0.077722	6.2990	3.51803	2.90340
17	F-4C/D	0.401693	14.1356	0.416707	0.71440	0.416707	0.008282	13.1477	2.23824	2.78004
18	F-8A/B/C	0.287896	13.9340	0.429935	0.75419	0.429935	0.013746	25.9000	1.55740	2.50057
19	F-14A	0.322389	8.2083	0.551448	1.27116	0.551448	0.220786	2.4458	1.61224	2.56774
20	F-15A	0.144474	22.8912	0.648508	1.84501	0.648508	0.061671	3.8983	5.73626	1.14878
21	F-16A	0.137905	17.9308	0.543439	1.18720	0.543439	0.183187	0.7037	1.58315	1.81200
22	F/A-18A	0.212188	13.4057	0.612743	1.58226	0.612743	0.024434	23.7059	5.53147	1.33313
23	F-84F	0.252978	12.1527	0.632302	1.71962	0.632302	0.129708	12.6316	2.61905	2.06450
24	F-86D	0.524858	12.2281	0.390251	0.29279	0.405683	0.000000	29.0500	2.89628	2.13650
25	F-86F	0.524858	12.2281	0.390251	0.29279	0.405683	0.000000	29.0500	2.89628	2.13650
26	F-89D	0.442748	26.7204	0.786260	3.81481	0.786260	0.351145	-0.2542	6.14600	3.34351
27	F-100D	0.226853	10.3570	0.694791	2.27645	0.694791	0.000000	6.7941	6.57800	2.97739
28	F-100A/C	0.364209	5.5067	0.527278	1.11543	0.527278	0.000000	26.5331	4.85947	1.55787
29	F-101A/B	0.153269	9.2358	0.660109	1.94212	0.660109	0.127701	6.4347	2.24652	2.71399
30	F-102A	0.343225	10.4758	0.585206	1.41083	0.585206	0.052095	29.9500	5.51813	2.08616
31	F-104A/B	0.285284	9.7892	0.673244	2.07099	0.673244	0.153846	12.3571	5.28346	2.25251
32	F-105B/D	0.347452	8.0990	0.526867	1.11357	0.526867	0.011012	15.3527	3.85439	3.53013
33	F-106A/B	0.307859	6.0990	0.621543	1.64231	0.621543	0.129016	17.3238	3.41411	2.22090
34	F-111A	0.306886	7.0700	0.519097	1.07942	0.519097	0.149000	12.3439	1.67677	2.53567
35	F-111D	0.179813	18.5763	0.633529	1.73490	0.633529	0.164928	1.5000	2.04668	2.44817
36	F-111F	0.153457	20.9766	0.691774	2.24505	0.691774	0.178220	0.1488	2.33091	2.35325

TABLE 5-4

RATIO DATA FOR ONE YEAR PRIOR TO PRODUCTION (Ratios 18- 25)

OBS	PNAME	PATRN1	INVTRN1	WCAPTRN1	NVS2SAL1	NVS2FUN1	NVS2ASS1	NVS2P1	NVS2DEP1
1	A-1E/G/H	8.5458	2.5065	4.5405	0.0476072	1.22989	0.062282	0.406844	5.9444
2	A-3A/B	16.9120	4.7677	10.6559	0.0148778	0.56115	0.031388	0.251613	2.5161
3	A-4C	14.6410	4.2082	10.5504	0.0168310	0.32517	0.042115	0.246422	1.0856
4	A-4M	10.9281	4.7167	18.8752	0.0328395	0.61639	0.065059	0.358872	2.2828
5	A-4A/B	6.8085	4.0272	10.3761	.	.	.	.	.
6	A-4E/F	15.4733	4.5462	12.4539	0.0062383	0.15345	0.019290	0.096526	0.4801
7	A-6A	13.1352	7.2419	10.1277	0.0228594	0.63874	0.070349	0.300262	1.6697
8	A-6E	8.8148	12.6540	11.3273	0.0335508	0.93661	0.105882	0.295743	1.9604
9	A-7D	10.1686	6.1117	7.0602	0.0759543	2.83600	0.167400	0.772350	11.2390
10	A-7E	10.1686	6.1117	7.0602	0.0759543	2.83600	0.167400	0.772350	11.2390
11	A-7A/8	16.0411	9.6957	9.1031	0.0084836	0.32732	0.021572	0.136096	0.7905
12	A-10A	10.6050	3.4798	5.8023	0.0221870	0.60970	0.037736	0.235294	1.7500
13	F-1B/C/M	14.3576	2.9204	4.2774	0.0480653	1.09193	0.074879	0.690101	6.1000
14	F-4E	12.1322	3.9131	7.9638	0.0177679	0.43472	0.034612	0.215565	1.3433
15	F-4J	12.1322	3.9131	7.9638	0.0177679	0.43472	0.034612	0.215565	1.3433
16	F-4A/B	14.5280	5.2335	17.1164	0.0274113	0.83906	0.079586	0.398233	2.7406
17	F-4C/D	14.9323	4.1316	6.9208	0.0017276	0.03328	0.004803	0.025797	0.1031
18	F-8A/8/C	9.0581	5.9039	8.6857	0.0232097	0.38481	0.058037	0.210235	1.1176
19	F-14A	7.5072	8.0869	7.9647	0.0195328	0.46973	0.050155	0.146636	0.9238
20	F-15A	10.1613	1.6543	7.9515	0.0000000	0.00000	0.000000	0.000000	0.0000
21	F-16A	5.2787	3.4965	13.1395	0.0298842	0.98411	0.054150	0.157751	1.0770
22	F/A-18A	12.0347	2.1827	6.2828	0.0372854	0.69495	0.049706	0.448718	2.5497
23	F-84F	8.5513	5.0900	8.1608	0.0790000	1.82114	0.210159	0.870499	9.1819
24	F-86D	27.3223	3.5425	3.0727	0.0072361	0.11518	0.015460	0.197708	1.1500
25	F-86F	27.3223	3.5425	3.0727	0.0072361	0.11518	0.015460	0.197708	1.1500
26	F-89D	28.8193	7.1678	7.5517	0.0031963	0.68293	0.010687	0.117647	0.5600
27	F-100D	28.8193	6.5821	13.1248	0.0040555	0.16423	0.012075	0.154104	0.8876
28	F-100A/C	14.3576	2.9204	4.2774	0.0480653	1.09193	0.074879	0.690101	6.1000
29	F-101A/8	9.2364	7.0918	17.7073	0.0294763	0.68823	0.079998	0.272256	2.6505
30	F-102A	19.6712	6.9234	6.0781	0.0078112	0.17850	0.016295	0.153655	1.0824
31	F-104A/B	17.6772	5.9341	7.8957	0.0161841	0.47391	0.036455	0.286089	1.9123
32	F-105B/D	25.8253	17.8802	10.1601	0.0100140	0.39264	0.035351	0.258616	2.4245
33	F-106A/8	12.1993	6.5460	7.2140	0.0526780	1.32664	0.116993	0.642637	7.8024
34	F-111A	8.1907	12.8635	8.2626	0.0221197	0.46736	0.056088	0.181174	1.0866
35	F-111D	7.9091	11.3989	13.6151	0.0253850	0.85246	0.062147	0.200772	5.6634
36	F-111F	7.9292	4.4430	15.3350	0.0487883	2.33588	0.114811	0.386852	2.4529

B. ANALYSIS OF RATIO MEASURES

1. Review of Independent Variables

The independent variables require some analysis to determine suitability for the planned regression analysis. As a first step to this end, the 25 ratios were subjected to a univariate analysis, including a plot of data to examine normality and a stem-leaf plot to assist in outlier analysis.[Ref. 17] This step helped identify probable outlier observations and to highlight any variables that might need transformation prior to regression analysis.

a. Outlier Processing Methods and Considerations

There are several methods of dealing with possible outlier data including:

(1) Disregard possible outlier data and include them in the analysis. This method was rejected because of the substantial effect that outlier data can have in influencing correlation and regression tests.

(2) Discard apparent outlier observations. This method removes the impact on correlation and regression tests. However, because several aircraft in the sample had apparent outlier data in one or more ratios the sample size for regression analysis would have been reduced significantly. Therefore this method was also rejected.

(3) Transform the ratio measures. Transforming data is possible using several methods including: log transformation, exponential transformation, power

transformation, square-root transformation, and inverse function transformation.[Ref. 18: chap. 4] Because of the large number of variables of mixed type (some positively valued, some negative, some zero-valued, some fractional less than one and some fractional greater than one) no single transformation would serve for all the variables in the sample. Therefore this method was also rejected.

(4) Truncation of outlier data. Truncation refers to establishing some maximum/minimum ratio value for each specific ratio being examined. More specifically, the distribution of ratio values is observed. Extreme outlier observations at both ends of the distribution are identified. A maximum and minimum value are, somewhat subjectively, set to establish a "reasonable" range for the ratio distribution. Then values falling above or below the range are truncated to the maximum or minimum boundaries of the range. In short, extreme (outlier) values are "pulled in" to form a more compact distribution. This method, although ad hoc, provides the best solution.

b. Outlier Processing

The process of identifying outlier ratios consisted of reviewing the stem-leaf and normal plots. Only values well outside of the normal distribution range were considered for truncation (40% larger or smaller than the nearest non-outlier ratio value). To maintain consistency in truncating the ratios the following methods were used.

(1) High outlier values: Assume one observation was identified with a ratio value that was an obvious outlier, much higher than other ratios in the distribution. The highest and second highest non-outlier values were then observed, and a percentage difference (increase) between the two values was determined. Assume the highest and second highest non-outlier data differed by 5%. The outlier was then truncated and assigned a new value at twice 5% (i.e., 10%) above the highest non-outlier value. More formally, the following formula was used to assign truncated values.

$$O_r = [(((D_F - D_{F-1})/D_{F-1}) \times 2) + 1] \times D_F$$

where

O_r = the outlier replacement value.

D_F = the highest non-outlier ratio value.

D_{F-1} = the second highest non-outlier ratio value.

The O_r value would then <u>replace</u> the outlier value.[1] A somewhat arbitrary limit of 20% was also established to limit replacement ratio value extremes. If more than 10% difference occurred between the two highest (non-outlier) ratios then the outlier value was replaced with a value only 20% larger than the highest non-outlier value.

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[1]. i.e. If D_F = 1.3 and D_{F-1} =1.2, then:
$O_r = [(((1.3 - 1.2)/1.2) \times 2) + 1] \times 1.3 = 1.52$
The resulting truncated data value would then be established as 1.52.

(2) Low outlier values. A similar technique was applied to low outlier ratios with the following formula.

$$O_r = [1 - (((D_{F-1} - D_F)/D_{F-1}) \times 2)] \times D_F$$

where

O_r, D_F and D_{F-1} are as defined above.

Again, the O_r value would then replace the outlier value.[2] A limit was also set such that truncated replacement values differed from the lowest non-outlier value by no more than 20%. This method also prevents replacement values from being less than zero if the non-outlier ratio was positively valued.

(3) "Inappropriate" negative data values. Although some ratios can be expected to take on negative values (Profitability ratios for example) other ratios would not be meaningful if negatively valued. An example of an inappropriate negative ratio for this study is an investment ratio. It is possible that plant and equipment assets were liquidated creating a net negative number for investment ratios. However, the intent was for investment ratios to reflect the value of added plant and equipment. To avoid inappropriate negative values a somewhat ad hoc procedure of

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[2]. i.e., if $D_F = 1.2$ and $D_{F-1} = 1.3$, then

$$O_r = [1 - (((1.3 - 1.2)/1.3) \times 2)] \times 1.2$$
$$= 1.015$$

The truncated outlier data value is then established as 1.015.

replacing negatively valued investment ratios with a zero-value was used.

2. Review of "Cleaned" Data

To document the means, standard deviations and range of the ratios of the "cleaned" data a second univariate analysis was performed. Table 5-5 shows the resulting means, standard deviations and range of the ratios. Performing a simple correlation allows an initial examination of relationships between variables. Table 5-6 shows the correlation analyses for cleaned ratio data.

As discussed in Chapter IV the more variables in a model the more likely there will be inadvertent intercorrelation resulting in degradation of model significance. Because of the large number of independent variables used in this thesis and the fact that they are essentially grouped into five financial aspects, it is obvious that strong intercorrelations between ratios (especially within the separate aspects) may exist.

The problem of intercorrelation is particularly problematic when attempting to build a meaningful regression model. One of the methods employed in later sections of this thesis is a "stepwise" regression process that inserts variables into a regression model looking for the maximum R^2 that can be gained per variable. Although the process does provide a reasonable method of searching for important models it will not discern variables that are highly

TABLE 5-5

INDEPENDENT VARIABLE MEANS, STANDARD DEVIATION AND RANGE

VARIABLE	N	MEAN	STD. DEV.	MINIMUM	MAXIMUM
ROASS1	36	.06144183	.02809132	-.00343511	.12078211
ROEQ1	36	.15003762	.06092289	-.01666667	.25318424
ROCAP1	36	.12066982	.05281924	-.00616138	.21505479
PROFMAR1	36	.02807948	.01286186	-.00102740	.05653280
GROMAR1	36	.10105651	.05195277	.02224171	.22110246
CURRAT1	36	1.59165645	.24981607	1.24261619	2.08560000
QUIRAT1	36	.77244903	.40159065	.11677647	1.74678899
REC2WC1	36	.84115789	.41456506	.08431034	1.91725235
WCAPRAT1	36	.27639362	.09908008	.10495971	.52485800
RECTO1	36	12.02368477	4.92457529	5.50674105	26.72040000
DETRAT1	36	.59926601	.10052463	.39025100	.78625954
DET2EQ1	36	1.64693239	.75501735	.29278749	3.81481481
CDETRA1	36	.60012335	.09873917	.40568300	.78625954
NCDETRA1	36	.11281269	.09966018	.00000000	.35114504
INTCOV1	36	11.79871264	10.03084335	-.15423729	29.95000000
DET2PE1	36	3.53263092	1.42621129	1.55729972	6.57800000
ASSTRN1	36	2.28824009	.58262415	1.14878053	3.53013031
PATRN1	36	13.83874391	6.51671379	5.27874818	28.81930000
INVTRN1	36	5.92860037	3.39274633	1.65431756	17.88021936
WCAPTRN1	36	9.21463618	3.94633225	3.07265306	18.87515605
NVS2SAL1	35	.02689375	.02134285	.00000000	.07900000
NVS2FUN1	35	.77551271	.71343692	.00000000	2.83600000
NVS2ASS1	35	.05808691	.04419570	.00000000	.16740000
NVS2P1	35	.31402234	2.60352240	.00000000	9.18190000

TABLE 5-6 (PART A)

RATIO CORRELATION TABLE

PEARSON CORRELATION COEFFICIENTS / PROB > |R| UNDER H0:RHO=0 / NUMBER OF OBSERVATIONS

	FRAMVAR	PLAIVAR	FLYVAR	ROASS1	ROEQ1	ROCAP1	PROFMAR1	GROMAR1	CURRAT1	QUIRAT1	REC2WC1	WCAPRAT1	RECTO1	DETRAT1
FRAMVAR	1.00000	0.97511	0.76042	0.24596	0.22640	0.32309	0.33904	0.21151	-0.01302	0.03147	-0.06959	0.04081	-0.02424	-0.12818
	0.0000	0.0001	0.0001	0.1677	0.2050	8.0659	0.0536	0.2374	0.9392	8.0628	8.7004	0.0216	0.0935	0.4772
	33	33	33	33	33	33	33	33	33	33	33	33	33	33
PLATVAR	0.97511	1.00000	0.78401	0.20310	0.10939	0.29726	0.33196	0.21043	-0.05973	-0.02574	-0.10440	-0.00160	0.06530	-0.08719
	0.0001	8.0000	0.0001	0.2568	0.2911	0.0930	0.0591	0.2398	0.7413	8.8869	0.5631	0.9930	0.7177	0.6295
	33	33	33	33	33	33	33	33	33	33	33	33	33	33
FLYVAR	0.76042	0.78401	1.00000	0.21065	0.20312	0.31868	0.37095	0.24903	-0.15742	-0.13996	-0.14743	-0.06047	0.10006	-0.09679
	0.8001	0.0001	0.0000	0.2175	0.2340	0.0502	0.0259	0.1430	0.3592	8.4156	0.3909	0.6915	0.2700	0.5744
	33	33	36	36	36	36	36	36	36	36	36	36	36	36
ROASS1	0.24596	0.20310	0.21065	1.00000	0.73052	0.85070	0.83462	0.33996	0.24153	0.46690	0.08521	0.34512	-0.32320	-0.60741
	0.1677	0.2569	0.2175	0.0000	0.0001	0.0001	0.0001	0.0431	0.1559	0.0041	8.6212	0.0393	0.0545	0.0001
	33	33	36	36	36	36	36	36	36	36	36	36	36	36
ROEQ1	0.22640	0.18939	0.20312	0.73052	1.00000	0.87692	0.50100	0.20531	-0.24173	0.10367	0.53450	-0.16001	-0.46600	0.00210
	0.2050	0.2911	0.2348	0.0001	0.0000	0.8001	0.8002	0.0917	0.1555	0.5474	0.0007	0.3480	0.0042	0.9903
	33	33	36	36	36	36	36	36	36	36	36	36	36	36
ROCAP1	0.32309	0.29726	0.31860	0.85078	0.87692	1.00000	0.60090	0.30365	-0.14727	0.16963	0.31007	0.02896	-0.34333	-0.29427
	0.0659	8.0930	0.0582	0.0001	0.0001	0.0000	0.0801	0.0209	0.3914	0.3226	0.0457	0.8669	0.0404	0.0815
	33	33	36	36	36	36	36	36	36	36	36	36	36	36
PROFMAR1	0.33904	0.33196	0.37095	0.83462	0.50100	0.60090	1.00000	0.51195	0.16180	0.29236	-0.16717	0.29659	-0.25174	-0.54407
	0.0536	8.0591	0.0259	0.0001	0.0002	0.0001	0.0000	0.0014	0.3455	0.0836	0.3298	0.0790	0.1306	0.0006
	33	33	36	36	36	36	36	36	36	36	36	36	36	36
GROMAR1	0.21151	0.21043	0.24903	0.33896	0.20531	0.30365	0.51195	1.00000	-0.09395	-0.05460	-0.19050	-0.06634	0.09381	-0.18779
	0.2374	0.2390	0.1430	0.0431	0.0917	0.0209	0.0014	0.0000	0.5857	0.7510	0.2650	0.7007	0.5063	0.2727
	33	33	36	36	36	36	36	36	36	36	36	36	36	36
CURRAT1	-0.01302	-0.05973	-0.15742	0.24153	-0.24173	-0.14727	0.16180	-0.09395	1.00000	0.72080	-0.41186	0.91496	-0.18692	-0.49000
	0.9392	0.7413	0.3592	8.1559	0.1555	0.3914	0.3455	0.5857	0.0000	0.0001	0.0126	0.0001	0.2750	0.0024
	33	33	36	36	36	36	36	36	36	36	36	36	36	36
QUIRAT1	0.03147	-0.02574	-0.13996	0.46698	0.10367	0.16963	0.29236	-0.05460	0.72888	1.00000	-0.05546	0.73675	-0.37475	-0.43620
	0.0620	0.8869	0.4156	0.0041	0.5474	0.3226	0.0836	0.7510	0.0801	0.0000	0.7400	0.0001	0.0243	0.0070
	33	33	36	36	36	36	36	36	36	36	36	36	36	36
REC2WC1	-0.06959	-0.10440	-0.14743	0.08521	0.53650	0.31007	-0.16717	-0.19050	-0.41106	-0.05546	1.00000	-0.46207	-0.52718	0.33153
	0.7004	0.5631	0.3909	0.6212	0.0007	0.0657	0.3298	0.2650	0.0126	0.7480	0.0000	0.0046	0.0010	0.0482
	33	33	36	36	36	36	36	36	36	36	36	36	36	36
WCAPRAT1	0.04081	-0.00160	-0.06047	0.34512	-8.16001	0.02896	0.29659	-0.06634	0.91496	0.73675	-0.46207	1.00000	-0.20827	-0.50045
	0.0216	0.9930	0.6915	0.0393	0.3480	0.8669	0.0790	0.7007	0.0001	0.0001	0.0046	0.0000	0.2229	0.0015
	33	33	36	36	36	36	36	36	36	36	36	36	36	36
RECTO1	-0.02424	0.06530	0.18806	-0.32320	-0.46600	-0.34333	-0.25174	0.09381	-0.10692	-0.37475	-0.52710	-0.20827	1.00000	0.13246
	0.0935	0.7177	0.2700	0.0545	0.0042	0.0404	0.1386	8.5863	0.2750	0.0243	0.0010	0.2229	0.0000	0.4412
	33	33	36	36	36	36	36	36	36	36	36	36	36	36
DETRAT1	-0.12818	-0.08719	-0.09679	-0.60741	0.00210	-8.29427	-0.54487	-0.18777	-0.49000	-0.43620	0.33153	-0.50045	0.13246	1.00000
	0.4772	0.6295	0.5744	0.0001	0.9903	0.0015	0.0006	0.2727	0.0024	0.8078	0.0482	0.0015	0.4412	0.0000
	33	33	36	36	36	36	36	36	36	36	36	36	36	36

TABLE 5-6 (PART B)

RATIO CORRELATION TABLE

PEARSON CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS

	FRAMVAR	PLATVAR	FLYVAR	ROASS1	ROE01	ROCAP1	PROFMAR1	GROMAR1	CURRAT1	QUIRAT1	REC2WC1	WCAPRAT1	RECTO1	DETRAT1
DET2EO1	-0.16891	-0.13708	-0.14699	-0.61523	-0.09272	-0.56276	-0.58831	-0.18667	-0.30999	-0.20760	0.25176	-0.53369	0.10503	0.95795
	0.3674	0.4461	0.3923	0.0001	0.5907	0.0297	0.0002	0.2757	0.0650	0.0009	0.1306	0.0467	0.2000	0.0001
	33	33	36	36	36	36	56	36	56	56	36	36	36	56
CDETRA1	-0.13622	-0.09230	-0.10103	-0.59952	0.00303	-0.29360	-0.53497	-0.18056	-0.48120	-0.62666	0.32482	-0.69526	0.15523	0.99951
	0.4565	0.6095	0.5577	0.0001	0.9860	0.0822	0.0000	0.2707	0.0030	0.0098	0.0532	0.0021	0.6517	0.0001
	53	55	56	36	36	36	56	36	36	36	36	36	56	36
HCDETRA1	-0.26526	-0.27567	-0.30630	-0.57324	-0.28566	-0.66518	-0.57810	-0.35648	0.06989	-0.08843	0.12555	-0.18306	0.14374	0.62191
	0.1357	0.1205	0.0692	0.0003	0.0912	0.0001	0.0002	0.0328	0.6856	0.6080	0.6656	0.2852	0.4030	0.0001
	33	33	36	36	36	36	56	36	36	36	36	36	36	36
INTCOV1	0.34530	0.32037	0.28353	0.63291	0.27710	0.55201	0.72787	0.28278	0.23780	0.40603	-0.26661	0.47488	-0.28566	-0.61897
	0.0491	0.0691	0.0938	0.0001	0.1010	0.0005	0.0001	0.0967	0.1625	0.0140	0.7160	0.0036	0.0939	0.0001
	33	33	36	36	36	36	36	36	36	36	56	36	36	56
DET2PE1	0.17567	0.24155	0.28321	-0.26168	-0.06659	0.00900	-0.01620	0.00011	-0.15891	-0.18283	-0.20827	0.05679	0.08941	0.46036
	0.3282	0.1757	0.0942	0.1231	0.6996	0.9586	0.9253	0.9995	0.3566	0.2850	0.2229	0.7422	0.6060	0.0072
	33	33	36	36	36	36	36	36	36	36	36	36	36	56
ASSTRN1	-0.03488	-0.07483	-0.16175	0.13847	0.12345	0.17271	-0.38580	-0.36272	0.20666	0.31830	0.35792	0.16741	0.03554	0.03510
	0.8472	0.6790	0.3459	0.4206	0.6732	0.3138	0.0201	0.0297	0.2265	0.0585	0.0321	0.3291	0.8370	0.8390
	33	33	36	36	36	36	36	36	36	36	36	36	36	36
FAIRN1	0.04544	0.05250	0.08438	0.25183	-0.00019	0.24054	0.13574	-0.15196	0.36526	0.41637	-0.23656	0.60971	0.07479	-0.10376
	0.8018	0.7717	0.6246	0.1384	0.9991	0.1576	0.6299	0.3763	0.0285	0.0115	0.1648	0.0001	0.6646	0.5670
	33	33	36	36	36	36	36	36	36	56	36	36	36	36
INVTRN1	0.05281	-0.00150	-0.04175	0.03248	0.10261	0.00994	-0.32707	-0.51415	0.19116	0.39792	0.42872	0.09033	-0.21938	0.05019
	0.7704	0.9934	0.8089	0.8508	0.5515	0.9541	0.0515	0.0013	0.2641	0.0162	0.0091	0.6414	0.1986	0.7713
	33	33	36	36	36	36	36	36	36	36	36	36	36	36
WCAPTRN1	-0.13870	-0.11744	-0.08763	-0.12979	0.22546	0.09692	-0.38203	-0.17309	-0.68902	-0.45401	0.62485	-0.75689	0.26393	0.39367
	0.4414	0.5151	0.6113	0.4506	0.1861	0.5739	0.0215	0.3127	0.0001	0.0054	0.0001	0.0001	0.1198	0.0175
	33	33	36	36	36	36	36	36	36	36	56	36	36	36
NVS2SAL1	0.07676	0.01379	-0.15083	-0.22152	-0.02880	-0.20071	-0.08144	-0.01615	-0.13670	-0.10215	0.09380	-0.16821	-0.27092	0.21476
	0.6763	0.9403	0.3871	0.2014	0.8696	0.2476	0.6419	0.9267	0.4336	0.5593	0.5920	0.3341	0.1156	0.2156
	32	32	35	35	35	35	35	35	35	35	35	35	35	35
NVS2FUN1	-0.12463	-0.15138	-0.31459	-0.44032	-0.24567	-0.41731	-0.36165	-0.12945	-0.10795	-0.13539	0.03669	-0.15525	-0.07897	0.38637
	0.4967	0.4082	0.0639	0.0081	0.1549	0.0126	0.0328	0.4586	0.5371	0.4381	0.8342	0.3732	0.6520	0.0219
	32	32	35	35	35	35	35	35	35	35	35	35	35	35
NVS2ASS1	0.04843	-0.01350	-0.19171	-0.16604	0.06139	-0.15081	-0.16780	-0.10447	-0.12958	-0.02600	0.25993	-0.20617	-0.26195	0.25716
	0.7926	0.9415	0.2699	0.3404	0.7261	0.3872	0.3353	0.5504	0.4581	0.8821	0.1316	0.2347	0.1285	0.1359
	32	32	35	35	35	35	35	35	35	35	35	35	35	35
NVS2P1	0.17011	0.09635	-0.05635	-0.08487	0.08986	-0.02785	0.06693	-0.02537	-0.07009	-0.00038	0.09002	0.00394	-0.39590	0.19008
	0.3520	0.5999	0.7478	0.6279	0.6077	0.8738	0.7024	0.8850	0.6891	0.9983	0.6071	0.9821	0.0186	0.2741
	32	32	35	35	35	35	35	35	35	35	35	35	35	35
NVS2DEP1	0.04809	-0.01460	-0.06286	-0.12986	0.06135	-0.08184	0.00601	-0.03146	-0.05916	-0.04632	0.05579	-0.00654	-0.33201	0.21996
	0.7938	0.9368	0.7198	0.4572	0.7263	0.6402	0.9727	0.8576	0.7357	0.7916	0.7502	0.9702	0.0513	0.2043
	32	32	35	35	35	35	35	35	35	35	35	35	35	35

TABLE 5-6 (PART C)

RATIO CORRELATION TABLE

PEARSON CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS

	DET2EO1	CDETRA1	MCDETRA1	INTCOV1	DET2PE1	ASSTRN1	PATRN1	INVTRN1	MCAPTRN1	NVS2SAL1	NVS2FUN1	NVS2ASS1	NVS2P1	NVS2DEP1
DET2EO1	1.00000	0.95925	0.66301	-0.61187	0.43782	0.14570	0.01290	0.08920	0.30750	0.13211	0.34678	0.18042	0.11692	0.15048
	0.0000	0.0001	0.0001	0.0001	0.0076	0.3965	0.9405	0.6069	0.0681	0.4493	0.0425	0.2997	0.5036	0.3882
	36	36	36	36	36	36	36	36	36	35	35	35	35	35
CDETRA1	0.95925	1.00000	0.62305	-0.61481	0.44433	0.03341	-0.08716	0.04481	0.38688	0.21021	0.38496	0.25301	0.18876	0.21834
	0.0001	0.0000	0.0001	0.0001	0.0066	0.8466	0.6132	0.7952	0.0198	0.2255	0.0224	0.1425	0.2775	0.2077
	36	36	36	36	36	36	36	36	36	35	35	35	35	35
MCDETRA1	0.66301	0.62305	1.00000	-0.72519	-0.08561	0.09886	-0.28539	0.22063	0.19087	0.19335	0.35577	0.27514	0.03669	0.08300
	0.0001	0.0001	0.0000	0.0001	0.6204	0.5662	0.0916	0.1960	0.2648	0.2658	0.0359	0.1097	0.8342	0.6355
	36	36	36	36	36	36	36	36	36	35	35	35	35	35
INTCOV1	-0.61187	-0.61481	-0.72519	1.00000	0.11042	-0.22678	0.32023	-0.22677	-0.47967	-0.05872	-0.28949	-0.18617	0.12888	0.01592
	0.0001	0.0001	0.0001	0.0000	0.5215	0.1835	0.0569	0.1875	0.0031	0.7376	0.0916	0.2843	0.4606	0.9277
	36	36	36	36	36	36	36	36	36	35	35	35	35	35
DET2PE1	0.43782	0.44433	-0.08561	0.11042	1.00000	-0.21771	0.54367	-0.22933	-0.23137	-0.21730	-0.16739	-0.35470	0.00692	-0.03641
	0.0076	0.0066	0.6204	0.5215	0.0000	0.2021	0.0006	0.1785	0.1745	0.2099	0.3365	0.0365	0.9685	0.8355
	36	36	36	36	36	36	36	36	36	35	35	35	35	35
ASSTRN1	0.14570	0.03341	0.09886	-0.22678	-0.21771	1.00000	0.37610	0.68668	0.39928	-0.32567	-0.16986	-0.07607	-0.30018	-0.29217
	0.3965	0.8466	0.5662	0.1835	0.2021	0.0000	0.0238	0.0001	0.0158	0.0562	0.3293	0.6640	0.0798	0.0885
	36	36	36	36	36	36	36	36	36	35	35	35	35	35
PATRN1	0.01290	-0.08716	-0.28539	0.32023	0.54367	0.37610	1.00000	0.11288	-0.25291	-0.52641	-0.41920	-0.52508	-0.26172	-0.30084
	0.9405	0.6132	0.0916	0.0569	0.0006	0.0238	0.0000	0.5121	0.1367	0.0012	0.0122	0.0012	0.1288	0.0791
	36	36	36	36	36	36	36	36	36	35	35	35	35	35
INVTRN1	0.08920	0.04481	0.22063	-0.22477	-0.22933	0.68668	0.11288	1.00000	0.23387	-0.11316	-0.03716	0.08137	-0.13375	-0.02673
	0.6069	0.7952	0.1960	0.1875	0.1785	0.0001	0.5121	0.0000	0.1698	0.5175	0.8322	0.6422	0.4437	0.8789
	36	36	36	36	36	36	36	36	36	35	35	35	35	35
MCAPTRN1	0.30750	0.38688	0.19087	-0.47967	-0.23137	0.39928	-0.25291	0.23387	1.00000	-0.04171	0.03037	0.12665	-0.16638	-0.16935
	0.0681	0.0198	0.2648	0.0031	0.1745	0.0158	0.1367	0.1698	0.0000	0.8120	0.8625	0.4685	0.3394	0.3308
	36	36	36	36	36	36	36	36	36	35	35	35	35	35
NVS2SAL1	0.13211	0.21021	0.19335	-0.05872	-0.21730	-0.32567	-0.52641	-0.11316	-0.04171	1.00000	0.90999	0.94711	0.92936	0.88885
	0.4493	0.2255	0.2658	0.7376	0.2099	0.0562	0.0012	0.5175	0.8120	0.0000	0.0001	0.0001	0.0001	0.0001
	35	35	35	35	35	35	35	35	35	35	35	35	35	35
NVS2FUN1	0.34678	0.38496	0.35577	-0.28949	-0.16739	-0.16986	-0.41920	-0.03716	0.03037	0.90999	1.00000	0.90239	0.80250	0.82027
	0.0425	0.0224	0.0359	0.0916	0.3365	0.3293	0.0122	0.8322	0.8625	0.0001	0.0000	0.0001	0.0001	0.0001
	35	35	35	35	35	35	35	35	35	35	35	35	35	35
NVS2ASS1	0.18042	0.25301	0.27514	-0.18617	-0.35470	-0.07607	-0.52508	0.08137	0.12665	0.94711	0.90239	1.00000	0.85632	0.91647
	0.2997	0.1425	0.1097	0.2843	0.0365	0.6640	0.0012	0.6422	0.4685	0.0001	0.0001	0.0000	0.0001	0.0001
	35	35	35	35	35	35	35	35	35	35	35	35	35	35
NVS2P1	0.11692	0.18876	0.03669	0.12888	0.00692	-0.30018	-0.26172	-0.13375	-0.16638	0.92936	0.80250	0.85632	1.00000	0.90396
	0.5036	0.2775	0.8342	0.4606	0.9685	0.0798	0.1288	0.4437	0.3394	0.0001	0.0001	0.0001	0.0000	0.0001
	35	35	35	35	35	35	35	35	35	35	35	35	35	35
NVS2DEP1	0.15048	0.21834	0.08300	0.01592	-0.03641	-0.29217	-0.30084	-0.02673	-0.16935	0.88885	0.82027	0.81647	0.90396	1.00000
	0.3882	0.2077	0.6355	0.9277	0.8355	0.0885	0.0791	0.8789	0.3308	0.0001	0.0001	0.0001	0.0001	0.0000
	35	35	35	35	35	35	35	35	35	35	35	35	35	35

intercorrelated, and this tends to result in less meaningful models. This requires some method to examine the ratio relationships independently. The correlation table provides that method. While any correlations from this process are extremely tentative, because of lack of control for other ratios, they do provide a crude examination of the ratio relationships.

The correlation information is therefore useful in selecting ratios to be grouped together for possible regression analysis and in eliminating some multivariate models from further consideration due to highly intercorrelated variables within the model.

The correlation table reflects each individual ratio's relationship with other variables in the table, including the three cost variances determined in Chapter III. By examining the correlations, indicating their relationship with cost variance (FRAMVAR, PLATVAR and FLYVAR), the degree to which each ratio is associated with the cost variances can be observed.

Table 5-6 reveals all profit ratios to be positively, as hypothesized, and reasonably highly correlated with cost variance (18 to 37%). It also indicates solvency ratios to be generally negatively correlated as hypothesized. Three of these solvency ratios (INTCOV1, DET2PE1 and NCDETRA1) seem to be fairly highly correlated with cost variances (near 20%). Table 5-6 also indicates that liquidity, activity and investment aspect ratios are generally negatively correlated with cost variances as hypothesized, although the correlations are quite small. In addition, NVS2FUN1 and NVS2ASS1 appear to be fairly highly correlated to FLYVAR (-31.7% and -19.1% respectively).

There are several exceptions to the hypothesized relationships. RECTO1 from activity, DET2PE1 from solvency, PATRN1 from activity, and NVS2P1 from investment tend to exhibit correlations with cost variance with signs contrary to those hypothesized. Explanations for these exceptions may rely on the ratio groupings within aspects.

Because the ratios presented in Table 5-6 resulted from a somewhat subjective selection process it is possible other ratios may exhibit high correlations with cost variance. However, the table does allow some conclusions about the aspects in general.

(1) Only the profit aspect ratios are consistently correlated with cost variance at an acceptable level.

(2) Although other ratios seem fairly highly correlated with cost variances, upon further analysis they are also often highly correlated with profit aspect ratios (NCDETRA1, INTCOV1, DET2PE1, NVS2FUN1, and NVS2ASS1 are generally correlated with profit margin ratios higher than they are with cost variances). This indicates that multivariate models utilizing both a profit ratio and one or

more of these ratios may experience significant intercorrelation problems.

3. Initial Univariate Tests of Hypotheses

Chapter IV presented hypotheses relating individual aspects, and later ratios, to cost variances. The correlation results presented in Tables 5-6 through 5-8 also provide an initial test of these relationships prior to performing the multivariate model regression analysis.

The hypotheses can be evaluated by comparing the hypothesized relationship of the "most representative ratio" for each aspect, as discussed in Chapter IV (section F.), and displayed in Table 4-1, with the actual relationships these ratios exhibit to cost variances. Table 5-7 presents a comparison, for the "best ratio" from each aspect, of the hypothesized and actual relationship to cost variance.

TABLE 5-7
COMPARISON OF HYPOTHESIZED AND ACTUAL RATIO RELATIONSHIPS

ASPECT	"BEST RATIO"	RELATION TO COST VARIANCE HYPOTHESIZED (TABLE 4-1)	RELATION TO COST VARIANCE ACTUAL (TABLE 5-5) (FRAME, PLAT, FLY)
PROFITABILITY	PROFMAR	+	+.34, +.33, +.37
LIQUIDITY	WCAPRAT	-	+.04, -.02, -.07
SOLVENCY	INTCOV	+	+.34, +.32, +.28
ACTIVITY	PATRN	-	+.05, +.05, +.08
INVESTMENT	INV2DEP	-	+.05, -.02, -.06

("+" indicates that "high" ratio values are related to overruns, and "-" indicates that "low" ratio values are related to overruns.)

The results of the comparison show profit margin and interest coverage to be clearly related as hypothesized.

The working capital ratio and investment to depreciation ratio are, overall, related as hypothesized. But, plant asset turnover is opposite to the hypothesized relationship as discussed in the correlation table results above. This indicates the more "active" a firm, regarding plant assets, the <u>less</u> likely it will be able to achieve cost savings. This finding is perhaps explainable. High activity indicates assets are being more fully utilized. Perhaps when capacity is being fully utilized the firm is less flexible in responding to problems or opportunities and this lack of flexibility results in higher costs. This outcome is somewhat surprising, however, as high utilization of capacity is usually equated with cost savings.

C. SUMMARY

The inconsistency between hypothesized relationships and actual results highlights a troubling aspect of the "story-telling" hypotheses presented in Chapter IV. The hypotheses reflect a rational, although hardly unique, possibility of explaining relationships between cost and financial data. There are other, perhaps equally plausible, "stories" that could be told to relate cost variances to aspects of financial condition.

The correlations between cost variances and ratios in Table 5-6 also may also serve another purpose. These correlations provide evidence of the actual univariate associations and thus provide an indication of which ratios may be most useful in explaining cost variances when used in the multivariate regression analysis. In a portion of the regression analysis to follow, ratios for each financial aspect that were found to have the highest univariate correlations with cost variance were combined into a single multivariate model. This step, and other regression tests, are discussed in the next chapter.

VI. REGRESSION ANALYSIS

This chapter discusses the regression analysis procedures and findings. Broadly speaking, the objective of the regression analysis was twofold:

1. To identify a regression model containing multiple independent variables which was most effective in explaining cost variances, and

2. To observe the coefficients of the individual ratios in the regression models to identify the nature and strength of relationships between financial ratios and cost variances.

Several different regression approaches were pursued to build a model that best demonstrates the relationship between cost variances and financial ratios. This chapter discusses three phases of regression analyses performed for the sample in this thesis. In each phase the three dependent variables (FRAMVAR, PLATVAR, and FLYVAR) were regressed on various ratios. The phases differ in terms of what ratios were included as independent variables and how those particular ratios were chosen. The criteria for choosing ratios to be investigated in each phase were as follows:

Phase 1: Ratios identified by the analysis in Chapter IV as being "most" representative of the five financial aspects.

Phase 2: Ratios identified in the previous univariate correlation analysis as having the highest pair-wise correlation with cost variances.

Phase 3: Ratios identified by performing a stepwise regression procedure.[1] In this phase the stepwise procedure was allowed to select from all candidate ratios the ones that jointly served to best explain variation in the dependent variable. Stepwise regression is a flexible procedure which provides the researcher with considerable latitude in controlling the variables that enter the model. Use of the stepwise procedure will be explained more fully in a later section.

A. CONSIDERATIONS IN THE CHOICE OF REGRESSION MODELS

The findings from the three phases of regression analysis are discussed separately below. Several indicators of statistical significance and other considerations used in the process of identifying "good" models and eliminating other models from consideration are first discussed briefly.

1. Evaluation of Models

Each regression output resulted in two statistics that are of primary interest; an "F-statistic" and the model's R^2.

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[1]. Stepwise regressions using the Statistical Analysis System (SAS) "MAXR" option were performed. The STEPWISE/MAXR process begins building models by selecting the "top" variable, in terms of R^2, for a single variable model. It then proceeds to look for the best two-variable model, in terms of R^2, by trying all combinations of variables. The process builds a "best model" for each level of variables in this method until all variables are included in the final "best model."[Ref. 17]

a. "F-statistic"

The F-statistic represents a measure of significance.[2] For this thesis values of 4.0 and higher were considered significant. Models that resulted in an F-statistic value less than 4.0 were eliminated from further consideration.

b. R^2 for the model.

The model´s R^2 indicates the percentage of variation in the dependent variable that is explained by the regression line.[Ref. 19] For this thesis R^2 values greater than 10% (.10 on the regression print-outs) were considered significant. Models containing more than one independent variable also have an "adjusted R^2" that reflects R^2 adjusted for multiple variable interaction effects on the model. For multivariate models the adjusted R^2 value was used for level of significance determination, with the same value (10% or higher) required for further consideration.

2. Evaluation of Individual Variables

Within a multivariate regression model each individual variable must also be examined to determine its significance and its relationship (positive or negative) to the dependent variable.

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[2]. For a detailed explanation of the F-statistic curve, degrees of freedom and function see Reference 19 Chapter 6, and pages 326-329, and 566-568.

a. F-statistic or T-statistic

The coefficients of individual independent variables can be evaluated using an F-statistic or t-statistic.[3] For the purpose of this level of analysis, any variable with an F-statistic of less than 3.5 or a t-statistic less than 1.87 was not considered significant. A multivariate model with one or more variables not significant was eliminated from further consideration.

b. "Sign" of Each Independent Variable

In all regression models, the signs of the coefficients of individual ratios were observed for "consistency." The purpose here was to identify models in which two ratios, both representing the same aspect of financial condition, entered a model with opposite signs. This can occur during the stepwise procedure, particularly if the two ratios are highly correlated. When this does occur, typically the first ratio to enter reflects the primary relationship between the financial aspect and the dependent variable, while the second ratio to enter captures only a secondary or marginal relationship. Models where inconsistent signs were observed were eliminated from further consideration.

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[3]. The t-statistic is the square root of F. Different regression procedures produce different statistics.

c. Intercorrelation Analysis

One further consideration in analyzing the regression models was to check for intercorrelation between independent variables. "Pairwise" correlations previously presented in Table 5-6 were used for this purpose. When separate independent variables are highly correlated, tests of significance of their coefficients become unreliable. Intercorrelation of independent variables in the range of approximately 50% or higher was considered, for this thesis, as justification for elimination of the model from further consideration.

B. ANALYSIS OF REGRESSION PHASES

This section contains a brief review of what regressions were performed in the three phases and then discusses what level of significance resulted from each phase.

1. First Regression Phase

The first regression phase was undertaken with the five independent variables hypothesized to be important indicators of cost variance in Chapter IV. These five independent variables are:

1. Profit Margin (PROFMAR1)
2. Working Capital Ratio (WCAPRAT1)
3. Debt Ratio (DETRAT1)
4. Plant Asset Turnover (PATRN1)
5. Investment to Depreciation (NVS2DEP1)

The SAS "REG" (regression) procedure was used, which provides a model F-statistic and independent variable T-statistics along with the model's R^2 and adjusted R^2. The result of using these variables to explain each cost variance was disappointing. The models were not significant with respect to the F-statistic for any of the three cost variances. Table 6-1 contains the specific F-statistic and adjusted R^2 information for these models.

Although the models were not significant, the coefficient for PROFMAR1 was significant in each model. This provides some initial confirmation that this aspect of financial condition may be related to cost over/underruns.

TABLE 6-1
F-STATISTIC AND ADJUSTED R^2 FOR FIRST PHASE MODEL

	F-statistic	Adjusted R^2
FRAMVAR	0.880	-0.0198
PLATVAR	1.015	0.0024
FLYVAR	1.723	0.0961

2. Second Regression Phase.

The second phase included in the regression models, the one ratio from each financial aspect with the highest correlation to the three cost variances, as determined from the initial correlation analysis displayed in Table 5-6. The ratio from each aspect with the highest average correlation to the three dependent variables presents a possible five variable regression model. The "top" five ratios from this initial correlation examination were:

1. Profit Margin (PROFMAR1)
2. Receivables to Working Capital (REC2WC1)
3. Interest Coverage Ratio (INTCOV1)
4. Working Capital Turnover (WCAPTRN1)
5. Investment to Funds Ratio (NVS2FUN1)

Again, the SAS REG procedure was utilized and again the results from this phase of regression analysis were disappointing. The models were not significant with regard to F-statistic, nor did the model "explain" a significant portion of the cost variances (adjusted R^2), for any of the three cost variances. Table 6-2 presents the F-statistic and R^2 for these models.

TABLE 6-2
F-STATISTIC AND ADJUSTED R^2 FOR SECOND PHASE MODEL

	F-statistic	Adjusted R^2
FRAMVAR	0.851	-0.0246
PLATVAR	0.787	-0.0356
FLYVAR	1.437	0.0604

Although the models were not significant, as also experienced in the first regression phase, the profit margin ratio in each model was significant. Once again this provides some confirmation that this aspect of financial condition may be related to cost over/underruns.

3. Third Regression Phase.

Because of the disappointing results obtained in the first two phases of regression analysis a different approach for searching for significant models was followed. This phase used SAS to search, statistically, for "best" ratios in the stepwise process described earlier. The SAS "STEPWISE/MAXR" procedure was used. One important advantage of using the stepwise process with large numbers of independent variables is that it tries numerous combinations of variables and displays several models leading up to a "best" multivariate model. This process of substituting variables, in a search for the "best" R^2 model for each level (number of variables), provides some added insight into the joint relationship of independent variables with the dependent variable. These relationships can be used in an attempt to identify a useful model which both minimizes correlation between independent variables and includes variables representing distinct aspects of financial condition.

Initially the stepwise procedure was conducted allowing the SAS program to select from any of the 25 independent variables to create a model best explaining cost variance. Results indicated that one ratio, profit margin, was important in explaining all three measures of cost variance. After selecting the PROFMAR1 ratio, the stepwise procedure would continue and often select a second ratio representing the profitability aspect of financial condition, typically with an opposite sign. As indicated previously, a model containing two ratios from the same financial aspect, with inconsistent signs, was considered undesirable.

Consequently the stepwise procedure was conducted a second time, allowing the procedure to select a total of one profitability ratio. This step did permit any additional ratio (of the 20 remaining non-profit ratios) to enter the model. This second step was conducted five times with a different individual profitability ratio used in the stepwise process each time.

The results from this phase produced numerous models of interest. However, a majority of the models displayed intercorrelation between at least two non profit-aspect variables high enough to be eliminated from further consideration. The end result of this phase of the analysis was the following. FRAMVAR and PLATVAR could best be explained using models that contained only a single ratio: PROFMAR1. When additional ratios were added to these models, the additional ratios were insignificant and the overall significance of the models declined. A model containing only PROFMAR1 also did comparatively well in explaining FLYVAR. However, a multi-ratio model was also significant.

4. Confirmation Analysis

Once the range of model possibilities was reduced it made sense to analyze the "best models" that appeared to be significant with a more detailed regression process. To this end the SAS REG (regression) procedure was used with an option to obtain residuals for the multivariate model.[Ref. 17] The residuals were then plotted against the independent variables contained in that model to perform a visual check for unseen interdependence or data irregularities.[Ref. 18] The objective was to verify that there were no patterns in the residual versus independent variable plots that indicated data was not normally distributed or that additional data transformations were needed.

Table 6-3 contains the three single variable regression models. The best multivariate model for FLYVAR is presented in Table 6-4. Plots of residuals versus independent variables for the most significant multivariate model are contained in Tables 6-5 through 6-8. The plots reveal no obvious patterns and are therefore confirmation that no further data transformation would yield a better model.

C. DISCUSSION OF RESULTS

The first finding of importance is that the single variable, PROFMAR1, tends to be the most consistent and significant predictor of cost variances across the three levels of cost. In fact for both FRAMVAR and PLATVAR,

TABLE 6-3

CONFIRMATION REGRESSION OF PROFMAR1 TO COST VARIANCES

FRAMVAR

DEP VARIABLE: FRAMVAR

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	31.11683792	31.11683792	4.026	0.0536
ERROR	31	239.58096	7.72841791		
C TOTAL	32	270.69779			

ROOT MSE	2.780003	R-SQUARE	0.1150
DEP MEAN	0.4710197	ADJ R-SQ	0.0864
C.V.	590.2095		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	-1.59099380	1.13588253	-1.401	0.1712
PROFMAR1	1	73.68838638	36.72371572	2.007	0.0536

PLATVAR

DEP VARIABLE: PLATVAR

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	33.37388509	33.37388509	3.839	0.0591
ERROR	31	269.48841	8.69317444		
C TOTAL	32	302.86229			

ROOT MSE	2.948419	R-SQUARE	0.1102
DEP MEAN	0.4871345	ADJ R-SQ	0.0815
C.V.	605.2577		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	-1.64835366	1.20469558	-1.368	0.1811
PROFMAR1	1	76.31408488	38.94848011	1.959	0.0591

FLYVAR

DEP VARIABLE: FLYVAR

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	42.25258915	42.25258915	5.425	0.0259
ERROR	34	264.81360	7.78863529		
C TOTAL	35	307.06619			

ROOT MSE	2.790813	R-SQUARE	0.1376
DEP MEAN	0.3760947	ADJ R-SQ	0.1122
C.V.	742.0505		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	-2.02261655	1.13003593	-1.790	0.0824
PROFMAR1	1	85.42578797	36.67693318	2.329	0.0259

TABLE 6-4

FLYVAR MULTIVARIATE REGRESSION MODEL

F
L
Y
V
A
R

DEP VARIABLE: FLYVAR

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	4	112.60385	28.15096290	4.488	0.0056
ERROR	31	194.46234	6.27297862		
C TOTAL	35	307.06619			

ROOT MSE	2.504592	R-SQUARE	0.3667
DEP MEAN	0.3760947	ADJ R-SQ	0.2850
C.V.	665.947		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	-5.65314237	2.03796605	-2.774	0.0093
PROFMAR1	1	146.49466	39.95277438	3.667	0.0009
QUIRATI	1	-3.18876232	1.31849906	-2.418	0.0216
DET2FE1	1	0.64024766	0.30707459	2.085	0.0454
INVTRN1	1	0.35710651	0.16018888	2.229	0.0332

TABLE 6-5

PLOT OF REGRESSION RESIDUALS VERSUS PROFMAR1

PLOT OF R1*PROFMAR1   LEGEND: A = 1 OBS, B = 2 OBS, ETC.

NOTE: 2 OBS HAD MISSING VALUES

TABLE 6-6

PLOT OF REGRESSION RESIDUALS VERSUS QUIRAT1

PLOT OF R1*QUIRAT1   LEGEND: A = 1 OBS, B = 2 OBS, ETC.

NOTE: 2 OBS HAD MISSING VALUES

TABLE 6-7

PLOT OF REGRESSION RESIDUALS VERSUS DET2PE1

NOTE: 2 OBS HAD MISSING VALUES

TABLE 6-8

PLOT OF REGRESSION RESIDUALS VERSUS INVTRN1

PLOT OF R1*INVTRN1   LEGEND: A = 1 OBS, B = 2 OBS, ETC.

NOTE: 2 OBS HAD MISSING VALUES

adding additional variables did not lead to better models. The coefficient for PROFMAR1 in these models was positive and reasonably significant. The positive coefficient was consistent with the original hypothesis and consistent with the idea that as a firm's efforts to increase profits do not contribute to cost savings to the customer, but lead to increases in product prices and, therefore, to cost overruns.

The multivariate model found to be a significant explanation of FLYVAR is perhaps more interesting and permits an opportunity to discuss findings related to some of the other hypotheses. The multivariate model is presented in Table 6-9. Note that the coefficients for PROFMAR1, DET2DEP1, and INVTRN1 are positive, while the coefficient for QUIRAT1 is negative. Cost overruns tend to be associated with higher values of each of the ratios with a positive sign and cost underrun is associated with the ratio with a negative sign.

TABLE 6-9
MOST SIGNIFICANT MODEL EQUATION

$$\text{FLYVAR} = -5.65 + (146.49\ \text{PROFMAR1}) - (3.19\ \text{QUIRAT1}) + (.64\ \text{DET2PE1}) + (.35\ \text{INVTRN1})$$

This multivariate model has an adjusted R^2 of .285 and an overall F-statistic of 4.488, as shown in Table 6-4. Although this model cannot be described as a strong predictor the model does indicate important relationships with cost variances that may be useful in analyzing flyaway cost variances. By examining the signs of the ratios in the equation in Table 6-9 four hypotheses of Chapter IV can be evaluated.

The hypotheses presented in Chapter IV predicted a positive sign for PROFMAR1 and negative signs for QUIRAT1, DET2PE1 and INVTRN1. The expected relationships between PROFMAR1 and QUIRAT1 were confirmed. If this equation is correct there must be explanations for the unexpected relationships found for DET2PE1 and INVTRN1. There are many possibilities, but the following paragraphs suggest plausible "stories" explaining the unexpected positive association between these ratios and cost.

1. **Solvency Aspect (Debt to Plant and Equipment)**

Financial leverage is an indicator of solvency or long term risk. High leverage implies greater risk, which implies a high cost of raising capital. The high cost of capital places constraints on the firm's ability to invest in capital assets or productivity enhancing programs. These constraints may result in less efficient production and highe' costs. Hence, a positive association between leverage (solvency) and cost may exist.

2. **Activity (Inventory Turnover)**

High activity indicates assets are being more fully utilized. As discussed in Chapter V, when capacity is being fully utilized a firm may be less flexible in responding to problems or opportunities. This lack of flexibility may result in higher costs. Hence, a positive association between activity and cost may exist [Ref 9: pp. 58-59].

D. MULTIVARIATE MODEL'S RELATIONSHIP WITH COST

The model's "meaning" can now be considered in terms of indicating cost overruns or cost underruns. Table 6-10 provides minimum, mean and maximum values for the four ratios in the model for sample firms. By examining "possibilities" within this range of ratio values the influence of individual ratios on cost can be considered.

TABLE 6-10
MODEL VARIABLE MINIMUM, MAXIMUM AND MEAN VALUES

	Minimum	Mean	Maximum
PROFMAR1	-0.001	0.028	0.057
QUIRAT1	0.12	0.77	1.75
DET2PE1	1.56	3.53	6.58
INVTRN1	1.65	5.93	17.88

Consider as a benchmark the predicted cost variance that would be expected for the "average" firm (i.e., a firm with mean values for each of the ratios). Such a firm would have a predicted FLYVAR as follows:

$$
\begin{aligned}
\textbf{FLYVAR} &= -5.65+(146.49\text{x}.028)-(3.19\text{x}0.77)+(.64\text{x}3.53)+(.35\text{x}5.93)\\
&= -5.65+\quad 4.10 \quad - \quad 2.46 \quad + \quad 2.26 \quad + \quad 2.08\\
&= +0.33 \text{ (the mean FLYVAR is an overrun of .33)}
\end{aligned}
$$

A slight cost overrun (.33) results.

Determining FLYVAR by replacing the mean value for each ratio with its <u>minimum</u> value independently in the regression equation, while holding the other three ratios at the mean, results in the following:

For **PROFMAR1**: 146.49 x -.001 = **-0.15**;
-5.65 - **0.15** - 2.46 + 2.26 + 2.08 = -3.92 (underrun of 3.92)

For **QUIRAT1**: -3.19 x 0.12 = **-0.38**;
-5.65 + 4.10 - **0.38** + 2.26 + 2.08 = +2.41 (overrun of 2.41)

For **DET2PE1**: .64 x 1.56 = **1.00**;
-5.65 + 4.10 - 2.46 + **1.00** + 2.08 = -0.93 (underrun of 0.93)

For **INVTRN1**: .35 x 1.65 = **0.58**;
-5.65 + 4.10 - 2.46 + 2.26 + **0.58** = -1.17 (underrun of 1.17)

In each case ratios with a positive sign result in noticeable cost underruns. QUIRAT1, with a negative sign, results in an overrun.

Determining FLYVAR by replacing the mean value for each ratio with its <u>maximum</u> value, in a manner similar to the process above, results in the following:

For **PROFMAR1**: 146.49 x .057 = **8.35**;
-5.65 + **8.35** - 2.46 + 2 .26 + 2.08 = 4.58 (overrun of 4.58)

For **QUIRAT1**: -3.19 x 1.75 = **-5.58**;
-5.65 + 4.10 - **5.58** + 2.26 + 2.08 = -2.79 (underrun of 2.79)

For **DET2PE1**: 0.64 x 6.58 = **4.21**;
-5.65 + 4.10 - 2.46 + **4.21** + 2.08 = +2.28 (overrun of 2.28)

For **INVTRN1**: 0.35 x 17.88 = **6.26**;
-5.65 + 4.10 - 2.46 + 2.26 + **6.26** = +4.51 (overrun of 4.51)

Because of the range and respectve coefficient of each of the ratios in the model, PROFMAR1 has the greatest influence on FLYVAR underruns, followed by QUIRAT1, INVTRN1 and then DET2PE1. Similarly, PROFMAR1 has the greatest influence on overruns, but is followed by INVTRN1 and then QUIRAT1 and DET2PE1. The multivariate model suggests that any, and in fact all, of the ratios with a positive sign can result in an underrun if they are sufficiently below the sample mean (and if all else is at or near the mean value). It indicates QUIRAT1 can result in an underrun if it is above the sample mean and all other ratios are at or near their mean value. It also suggests that all three "positive" ratios can result in overruns if they are at or above the mean value, while QUIRAT1 can result in an overrun if it is below the mean.

These calculations do confirm the earlier discussions regarding the sign of the ratio being related to an over/underrun.

E. CHAPTER SUMMARY

Through various regression analyses, significance tests, and intercorrelation analyses three models have been determined to have significant relationships with specific production cost variances. Profit margin in particular, was significant in explaining airframe, platform and flyaway cost variances. Of particular interest was the four-ratio model that may be potentially useful for indicating a tendency for a cost over/under-run at the flyaway aircraft cost level.

Chapter VII will present conclusions and recommendations based on the results presented in this chapter.

VII. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

The were two primary objectives of this thesis. The first objective was to investigate measures of financial condition that may serve as explanations of cost overruns or underruns experienced during the procurement of major DOD aircraft weapon systems. The second objective was to identify conditions that are associated with cost overruns or underruns that may provide an initial step toward prediction of future costs of new, high-technology, aircraft systems.

As a basis for analyzing cost overruns and underruns for multiple manufacturers, measures of technology and cost were developed. The process used relied on a recent study that combined technology measurement with aircraft production cost measurement. The study developed measures of estimated cost as a function of technology and compared these cost estimates with actual costs to create measures of cost variances (cost overruns or underruns).

Technology measures were initially created for three components of aircraft:

1. Platform Technology (PLATTECH)
2. Avionics and Weapon Systems Technology (SYSTECH)
3. Flyaway Aircraft Technology (FLYTECH)

These measures for aircraft technology were created using a judgmental multi-attribute utility function and reflected common characteristics for aircraft such as payload, range, maneuverability, speed and survivability. [Ref. 9] The three technology measures were independently regressed against the year aircraft were first manufactured. The resulting regression models produced two measures of technology for each aircraft technology component:

1. "STAND," which was a measure of the level of technology at one point in time, or the state-of-the-art of technology.

2. "ADVANCE," which was a measure of the extension in technology beyond the state-of-the-art for a particular aircraft.

The technology analyses were conducted using a sample of 47 conventional-take-off-and-landing, fighter or attack mission, military aircraft produced between the 1950's and the 1980's.

Measures of production cost were developed by creating a cumulative average cost (CAC) of 100 units (in FY81 dollars). The result of calculating a CAC was an average cost per unit if 100 aircraft were produced. Cost data was developed for three cost categories:

1. Airframe Cost (FRAMCOST).
2. Airframe plus Engine Cost (PLATCOST).
3. Total Flyaway Cost (FLYCOST).

Each of the measures of cost were regressed on measures of STAND and ADVANCE. Results established that both STAND and ADVANCE were highly significant in explaining cost. Measures of cost variances (overruns or underruns) were then created by comparing actual production cost with regression model predicted cost.

The next step was to describe five aspects of financial condition (profitability, liquidity, solvency, activity and investment) and the expected relationships between these aspects and production costs. Common financial ratios were introduced as a way to quantify measures of each financial aspect. 25 ratios were discussed and categorized into the five aspects. One ratio that "best" represented each aspect was proposed. The expected relationships of each "best" ratio to cost over/underruns were then discussed. These steps formed the basis for correlation and regression analysis of the relationships between financial condition (described by ratios) and cost variances.

The final analysis was conducted using a sample, reduced due to incomplete financial data, of 36 aircraft. This analysis resulted in two findings:

1. Higher profitability, as measured by profit margin, was associated with higher cost variances. This was true for all three cost components. This is consistent with a general tendency that contractors exhibiting high profitability experience subsequent cost overruns.

2. Three other aspects of financial condition were identified that were additionally related to flyaway aircraft cost. Flyaway aircraft cost tended to increase for contractors that were less solvent (higher values of debt to plant assets), less liquid (lower values of the current ratio) and more active (higher values of inventory turnover).

Finally, the relationships were examined for their consistency with hypotheses relating ratios to cost variances presented earlier in the thesis. Although the profit aspect and liquidity aspect ratios agreed with the hypotheses, solvency and activity aspect ratios were contrary to hypothesized relationships in the multivariate model. Plausible "explanations" for these unexpected relationships were then briefly described.

B. CONCLUSIONS

Based on the generally low significance levels , and relatively small "explanation" of cost variances the author is lead to conclude that financial condition is not a strong predictor of cost variances. Certain financial condition indicators do indicate, however, a tendency towards cost overruns or underruns. As a single-ratio indicator, profit margin has the strongest influence on, and is the best indicator of, cost variances. This is particularly true for airframe cost and flyaway cost variances.

One multi-ratio relationship also appears useful in examining tendencies toward flyaway aircraft cost variance:

$$\textbf{FLYVAR} = -5.65 + (146.49 \text{ PROFMAR1}) - (3.19 \text{ QUIRAT1}) + (.64 \text{ DET2PE1}) + (.35 \text{ INVTRN1})$$

C. RECOMMENDATIONS

Financial condition is somewhat useful as an indicator of cost variances. However, because cost appears to be so closely related to technology levels, the areas of technology measurement seem to play a far more important role in estimating and anticipating cost. Establishing consistent criteria for technology measurement and maintaining records for all "components" of technology would improve the basis for predicting and monitoring costs.

Utilizing financial condition with other cost indicators may provide a better "big-picture" of potential or expected cost variances. Other cost indicators may include such considerations as time-factored financial data (examining financial aspects over several years), related commercial sales within government contractor firms or the age of a firm (or its government contract branch).

The relationships determined between financial condition and cost variances in this thesis could also be examined for other areas. The areas lending themselves to additional research include determining if these indicators are common to government contractors only, or are they also indicators in traditional market industries of high-tech production processes.

It is recommended that financial condition analysis be used either as a starting point for predicting cost variances, or as a possible confirming check of other indicators of cost variances, but not as an answer unto itself.

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c.1 Financial condition of Government contractors and control of production costs in the procurement of major DOD aircraft weapon systems.